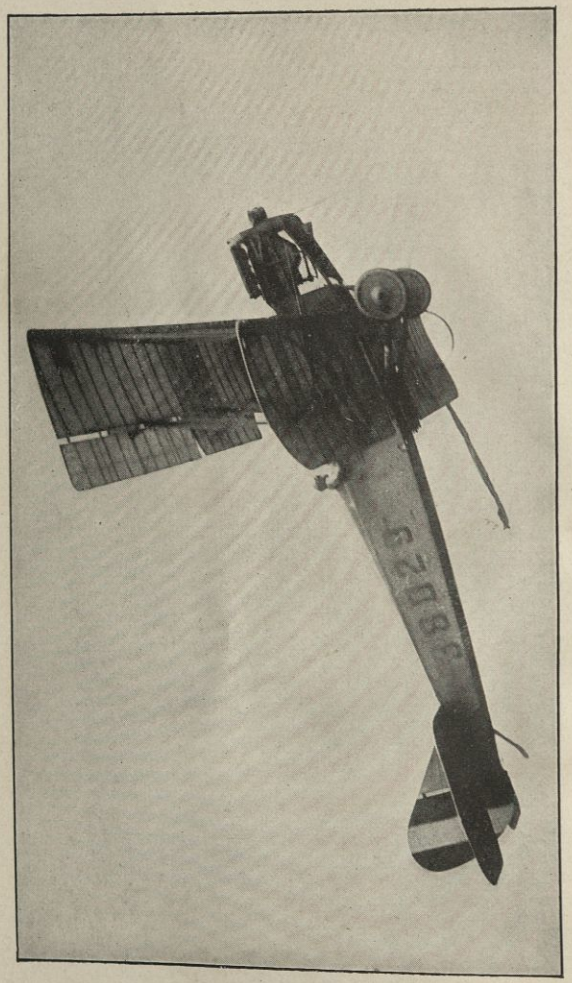

A BOMBING PLANE WITH BOMB IN POSITION

THE STORY OF MODERN SCIENCE

By

HENRY SMITH WILLIAMS

IN TEN VOLUMES
ILLUSTRATED

VOLUME VIII

SUPER-ENGINES OF WAR

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CONTENTS

VOL. VIII.—SUPER ENGINES OF WAR

CHAPTER PAGE

I—DISCOUNTING HUMAN LIFE IN WAR . 1
Nobel's discoveries—Nobel's dream of peace—Science and the peace problem—Making warfare more destructive—The new attitude of mind—Can science banish war?

II—A FEW LESSONS FROM THE WAR EXPERIENCE 14
The art of killing men—The Haber process of nitrogen fixation—Poisonous gases—American inventions—"Big Bertha"—The gasoline engine—Submarine activities countered by scientific developments—Medical activities—The Dakin-Carrel antiseptic—The Wright anti-typhoid vaccine—The airplane revolutionizes tactics.

III—MODERN EXPLOSIVES 27
The rapid conquests made by German siege guns—The new explosives—How explosives act—Gunpowder and high explosives—The power of numbers—Modern substitutes for gunpowder—The effects of high explosives—Why do explosives explode?—Dye stuffs and explosives—The deadliest weapon ever devised—Disarmament and war—Military old clothes.

CONTENTS

CHAPTER — PAGE

IV—How the Gas Engine Helped 62
The 5,000-ton *Selandia*—A steamless steamship—An all-important mechanism—Automobile and submarine—The dirigible balloon—The true flying machine—High flying—The hydroairplane Practical uses of the airplane—Experimental bomb-dropping — Anti-aircraft guns.

V—Aspects of Land Warfare 90
Laying down a barrage—Principles of range-finding—To kill a man at one mile—Shooting at the invisible—To hit a city at seventy miles—A five-hundred mile gun?—The flight of a bullet—A thousand bullets a minute—The machine gun is effective but not efficient —The man behind the gun—Mechanical perfection versus human skill.

VI—Aspects of Maritime Warfare 111
Warships torpedoed by submarines—Early history of the submarine—Capacities and limitations of the submarine—The failure that sank 5,000 ships—Loss of merchant tonnage—Why the submarine failed—The ears of a ship—Breaking the battleship's nose—The airplane carrier.

VII—Why the Zeppelin Failed 132
Great things expected of the Zeppelin—The old-fashioned balloon comes back—Hydrogen and helium—The hot-air balloon—Possible application of an old principle—A new era in ballooning—A new aspect of the conservation problem —Why the helium supply should be conserved.

VIII—What the Airplane Accomplished . . 148
The airplane duello—Scouting services of the airplane—The Lewis gun—Bomb-dropping airplanes—The principles and practise of bomb-dropping — Sinking warships—A bomb heard round the world.

IX—Grappling With Disease 168
The relative harmlessness of bullets—The triumph of modern surgery—The Japanese experience—Applying the new knowledge in the World War—Killing the death rate—The one great surgical lesson of the war—What medicine did for our armies—Our youth 58 per cent defective—Grouping physical defects by territories—What causes goiter?

X—Aspects of Recent Airplane Development 197
A fast and slow airplane—The turbo-booster and high flying—Electric clothing—Seeing from an airplane—Temperamental horizon lines—A magic wand of the air—Snubbing the Atlantic —Round the world in twenty-four hours—A new type of airship—The airplane as a farm implement—Gliding versus flying—Practical flying—Safety in the air.

CONTENTS

LIST OF ILLUSTRATIONS

Volume VIII

FOLLOWING PAGE

A Bombing Plane With Bomb in Position—*Frontispiece*

The Original Wright Biplane and Sixteen Pursuit Planes in Battle Formation—Recent British War Tank Going Over a Hurdle and Smashing a Tree at Aldershot—An Armored Car in Ireland and the Christie Amphibious Battle Tank—Lieut. Maughan and the Curtiss Biplane and General William E. Mitchell—Dornier Monoplane Flying Boat of 1916 and NC-4, the American Flying Boat That Crossed the Ocean in 1919—The Smallest Man-Carrying Balloon — An Army Dirigible and a Captive Observation Balloon—President Harding Arrives at Newport News, and ZR-1 the World's Largest Dirigible. 24

Navy F5L Bombers, and the Bombing of the Frankfurt — The Dreadnaught Ostfriesland Sunk by Bombing Planes in Twenty-one Minutes—Bomb-smashed Turrets of the Indiana, and a "Second Salvo"—Early Gliding Experiments of the Wright Brothers at Kittyhawk—Flying "Hands Off" With New Sperry Gyro Stabilizer—Aviator Lawrence Sperry in His Gyro Hydroairplane, and the Generator Drive and 72

LIST OF ILLUSTRATIONS

FOLLOWING PAGE

CONSTANT-SPEED TRANSMISSION APPARATUS ATTACHED TO CURTISS OX MOTOR—DESTROYERS THROWING OUT A SMOKE SCREEN, AND GAS-MASK DRILL ON BOARD THE PENNSYLVANIA.

SEARCHLIGHT INVENTED BY ELMER E. SPERRY—GIGANTIC SEARCHLIGHTS USED TO REVEAL AIRCRAFT AND TO ILLUMINATE AVIATION FIELDS—COMPLEX INTERNALS OF A SUBMARINE—DR. MILLER REESE HUTCHINSON AND A MODEL OF HIS "TWO-HUNDRED-MILE GUN", AND A LIGHT MACHINE-GUN INVENTED BY GEN. JOHN T. THOMPSON — GABRIEL POULAIN AND HIS MAN-PROPELLED "CYCLOPLANE", AND ARTHUR DRAPER OF THE U. S. BUREAU OF MINES TESTING MOTOR FUELS—BAROGRAPH THAT RECORDED THE 34,910-FEET ALTITUDE FLIGHT OF ROHLFS, AND BALANCE FOR TESTING WIND-RESISTANCE OF AIRPLANE MODELS—A MAIL-CARRYING AIRPLANE READY FOR ACTION—RECORD OF AN AIRPLANE DUEL WITH CAMERA-GUNS. 120

AVIATOR PREPARED FOR EMERGENCIES—EUROPEAN PASSENGER PLANES WITH SIDE ENTRANCE AND FRONT ENTRANCE—INTERIOR OF CURTISS "EAGLE" PASSENGER PLANE—"ALL ABOARD" AT COMMERCIAL AIRPLANE STATIONS NEAR PARIS AND BERLIN — COMMERCIAL FLYING BOAT SERVICE BETWEEN NEW YORK AND ATLANTIC CITY, AND AEROMARINE FIVE-PASSENGER FLYING BOAT—TWO VIEWS OF WILSON DAM AT PROJECTED NITRATE PLANT AT MUSCLE SHOALS—BUREAU OF MINES EXPERTS DOING RESEARCH WORK ON HELIUM GAS—SPRAYING ORCHARDS WITH INSECTICIDE FROM AN AIRPLANE. 168

The Story of Modern Science

VOLUME VIII

SUPER-ENGINES OF WAR

SUPER ENGINES OF WAR

CHAPTER I

DISCOUNTING HUMAN LIFE IN WAR

NOBEL'S DISCOVERIES

AWAY back in the year 1867, a young Swede named Alfred Nobel made a momentous discovery, quite by accident. He had been experimenting at Stockholm with an interesting but hitherto unimportant liquid known as nitroglycerin, and he accidentally spilled some of the liquid on the floor of his laboratory. The floor was composed of a chalky earth, and he observed that this absorbed the nitroglycerin.

Now it chanced that precisely what the young investigator was seeking was some substance that would absorb nitroglycerin and thus make it portable. The chalky earth of his laboratory floor supplied exactly the material he had been vainly seeking. In effect, the accidental spilling of the nitroglycerin constituted the discovery or invention of the substance soon to be world-famous as dynamite,—the earliest type of high explosives.

At a subsequent date, another accidental observation gave Nobel the basal idea for high explosives of nitro-celluloid type. He had injured his finger, and was using collodion to cover the abrasion and make it impervious to his chemicals.

Having the collodion thus at hand, he was led to mix a portion of it with nitroglycerin; and a usable paste resulted, which, variously modified, became the basis for numerous high explosives, including smokeless powder.

His work in developing high explosives made Nobel rich and famous. All the world was yearning, apparently, for just such energy-storing materials as he had developed; and it was recorded in the relatively peaceful first decade of the present century that industries having to do with the production of explosive nitroglycerin compounds had an annual output of something like 125,000,000 pounds, representing a value of a quarter of a million dollars, and giving employment to more than twelve thousand workers.

Then came the big war, and the industry of making high explosives at once assumed proportions dwarfing all antecedent records. Collective figures are not available,—the mind could not grasp them if they were,—but a vague comprehension of their significance comes to us in the wake of such a statistical fragment as the report that the British army alone discharged a million *tons* of explosive projectiles on the Western front in the second half of the year 1917.

The net result of the utilization of Alfred Nobel's discovery in the years 1914-1918 was the blotting out of five or six million human lives and the hideous mangling of human bodies in phalanxes of millions not yet accurately numbered.

A stupendous sequel that to the trifling accident of spilling a few drops of an unimportant liquid on the floor of an obscure laboratory of an unknown investigator up in Stockholm.

NOBEL'S DREAM OF PEACE

And note now this ironical paradox. That obscure young inventor, Alfred Nobel, was an idealist—a dreamer. To be sure he attained practical success and monetary reward as most dreamers do not; yet he remained an idealist to the last. It was his fervent belief that in developing high explosives and thereby supplying the world with agencies of hitherto unexampled destructiveness, he was taking a long step toward making warfare impossible.

If war is made sufficiently destructive, he argued, the nations of the world will fear to go to war. No potentate or governing body will send an army into the field to face total annihilation.

That Nobel was sincere in this belief, there can be no question. He left his entire fortune, as all the world knows, to found a series of prizes, each prize aggregating nearly forty thousand dollars annually, one of the prizes to be given specifically for the work most tending to promote the interests of peace. He died serene in the conviction that he had contributed vastly to the welfare of humanity; that his high explosives would be used universally in the industries of peace; and that by the silent warning of their destructive possibilities they would serve as a guarantee against wars between intelligent and highly civilized nations throughout the future.

Such was the dream of Alfred Nobel. And twenty years after his death the world was given over to a saturnalia of carnage. Europe was a holocaust of high explosives; thousands of acres of once fertile territory had been made into blood-stained crater fields; cities had been devastated

and villages obliterated; and along hundreds of miles of battle lines the menacing roar of cannon, the rattle of machine guns, and the crash of bursting shells were almost as continuous and inescapable as if they were a part of the orderly sequence of natural phenomena associated with the whirling of the earth on its axis.

Every sound told of the utilization of energy stored in the way Alfred Nobel had taught his fellows how to store it.

Not only that, but other menacing supplies of potential destructiveness were anchored beneath the surface of vast stretches of the sea, in the form of mines, or were sent hurtling in torpedoes to effect the destruction of thousands of ships. And that nothing might be lacking to complete the picture, uncounted additional tons of high explosives were dropped from the skies upon the heads, not alone of soldiers under arms but of the unoffending populations of cities, where women and children were the most likely victims.

From all of which it is clear that the immediate results of Alfred Nobel's efforts to make war impossible were not such as to enhance his standing as a prophet.

SCIENCE AND THE PEACE PROBLEM

And yet, if we look a little deeper, it may be that we shall find reason to believe that Nobel's idea of making warfare impossible by making it dishearteningly destructive was not without viability. If to-day all over the world earnest people are united in the effort to find a way to prevent future wars, it is chiefly because of the universal horror aroused by the carnage wrought by high

explosives in the recent war. And I think it may fairly be said that the best prospect of peace between the great nations of the world in the future lies in the logical extension of Alfred Nobel's idea of supplying means to make warfare still more destructive.

If this view is accepted, the problem of world peace seems to be essentially a problem in applied science. And it is almost axiomatic to say that the solution of the problem should not be left entirely to the military class. The military man is by profession a follower of tradition. He becomes as a matter of course institutionalized. He becomes a part of a machine that works according to established rules. In studying established systems of tactics he is of necessity backward-looking,—hampered by precedent and preconception. Almost as a matter of course he is non-receptive to ideas tending to disturb the old order of things. His idea of progress is to make cannon of the old type but of larger caliber; to make battleships of greater tonnage and thicker armament, but not departing greatly from the antecedent models.

Tangible illustrations of this natural conservatism of the military authorities are found in the refusal to utilize the Holland submarine boat in the Spanish-American War; in the non-acceptance of Hiram Maxim's machine gun until he had introduced it in England, after which it came back to America; in the more recent similar treatment of the inventor of the Lewis gun,—who, by rare exception, was himself a military man,—and in the attitude of the authorities toward the Wright Brothers when they had invented the

airplane, but were not allowed even to exhibit it officially until nearly five years after they had made demonstrations in private.

Nearly all the salient devices that have revolutionized modern warfare have been of non-military origin. These devices are the steel ship-turret, invented by John Erickson; high explosives introduced by Nobel; the machine gun perfected by Sir Hiram Maxim; the submarine boat perfected by Holland; the airplane perfected by the Wright Brothers; the telephone invented by Graham Bell; wireless telegraphy perfected by Signor Marconi; and preventive inoculation against typhoid fever, introduced by the English physician, Sir Almroth Wright.

Obviously, then, it is of the utmost importance that the problem of making war methods effective in the interest of peace should engage the attention of civilians, and in particular of scientific men of imagination. The recent war was lost by the Germans simply because they had not the imagination to see what manner of invention was imperatively necessary to their success. If they had devised a really swift submarine boat, or a non-explosive balloon—neither of which inventions lies beyond the reach of present-day ingenuity—they might in all probability have won the war. Their failure was humanity's gain, but the lesson should not be lost.

MAKING WARFARE MORE DESTRUCTIVE

So it would appear that an important function of a League of Nations for the maintenance of peace would be the consideration of essential inventions and improvements in the mechanism of

warfare. There is every reason to believe that science could give us within the next few years a submarine boat faster than any existing ship of war, which therefore would make all battleships obsolete; and a balloon actuated by non-explosive gases—for example, heated air if helium is not available—capable of encircling the world and with capacity to re-fuel without making a landing.

Under these conditions, and with the use of the noxious gases that were utilized with such deadly efficiency in the recent war, it would readily be possible to send out from a central station in Europe, in America, or in Asia, a squadron of airships that could totally annihilate the population of any city within a radius of five thousand miles; or a fleet of submarine boats that would clear the ocean of all hostile shipping.

It is true that efforts were made at the Peace Conference to abolish submarine boats; but such an effort to legislate out of existence an important instrument of warfare could hope for no other sequel than that which attended the decision of the first Hague Peace Conference to prohibit the throwing of explosive projectiles from balloons and all use of poisonous gases in warfare.

A suggestion that the total population of cities may be destroyed by perfected gas bombs and incendiary bombs from balloons would seem too barbarous for consideration had we not the evidence of recent history to tell us that when the armistice came in November, 1918, preparations were being made on the most magnificent scale to launch from balloons and airplanes avalanches of

tanks each containing a ton of gases so noxious that no living creature, from man to the smallest insect, would be left alive within a wide radius of the point where the tank exploded.

The use of poisonous gases seems an incredible barbarism; but it had become a commonplace long before the war was over.

Even more terrifying is the use of "liquid fire," which came into vogue toward the close of the war. This is in effect a modification of the famous "Greek fire" which went a long way toward revolutionizing warfare in the middle ages. The secret of the composition of the "Greek fire" has not come down to us; but it is surmised to have utilized quick-lime which bursts into flames when brought in contact with water, and was therefore sometimes spoken of as liquid fire. The possession of the secret enabled the Byzantine authorities to defend Constantinople on various occasions against hostile invaders.

Modern chemistry is familiar with many substances which would act as effective substitutes for the famous "Greek fire." These have been extensively utilized in pyrotechnic displays, but their military application until recently has been chiefly for the purpose of signaling and for illumination at night to disclose the whereabouts of the enemy and prevent surprise. Latterly, however, it has become evident that streams of incendiary material comparable to the "Greek fire," might advantageously be utilized to spray enemy trenches of machine-gun nests.

Had the war continued another year, it seems probable that materials of this character, together

with noxious gases, would, to a large extent, have taken precedence over fire arms of all types in short-range offensive and defensive action. Such would, for example, be the logical defense against the armored tanks which made playthings of barbed wire entanglements and machine-gun nests.

The scientific principle underlying the action of such incendiary materials is no different from that applying to explosives. In each case, what takes place is a chemical reaction consisting essentially of the union of oxygen with other materials. But the tangible character of the results depends largely upon the rapidity of this action. Explosives, and in particular high explosives, are so constituted that ignition (the application of heat) results in an almost instantaneous reaction throughout the mass of explosive material. But where a slower and more prolonged effect is desired, as in the case of "Greek fire" and its modern equivalents, the oxidizing agents, such as niter and potassium chlorate, are mixed with substances that oxidize with relative showness,—various sugars, starch, resins, compounds of sulfur with arsenic and antimony, and powdered metals including iron, zinc, antimony, and copper; various non-inflammable substances being utilized to graduate the effect.

In other words, the materials familiarly used in the preparation of fire-works, the destructive possibilities of which have been made only too familiar in the old-fashioned Fourth of July celebration, may be utilized with overwhelming effect in actual warfare.

THE NEW ATTITUDE OF MIND

All this implies not so much new knowledge as a new attitude of mind with regard to permissible methods of overcoming an enemy in warfare. Had not the Germans overturned all rules and started out on a campaign of unlimited "frightfulness" the world to-day would still look with horror on such methods. But a final lesson of the recent war appears to be that when a supposedly civilized nation runs amuck, it must be expected to utilize all the means of destruction that science has revealed, and that the enemies of that nation must fight fire with fire. The effective use of poisonous gases and incendiary bombs by the Allies, and their rumored intention to annihilate the population of German cities with gas-bombs dropped from airplanes, were cogent factors in bringing about the collapse and capitulation of the originators and instigators of the régime of unlimited frightfulness in warfare.

And in that fact, the Utopian dream of Alfred Nobel finds a measure of verification. "Make war destructive enough," he said, "and people will fear to go to war."

It begins to look as if that estimate, as an abstract proposition, was correct. But Nobel's discoveries did not by themselves supply material to make the application of the formula effective. High explosives are destructive, but they are not destructive enough. It required the evolution of the airship, and the clearing away of all prejudice against the use of the destructive possibilities of noxious gases and incendiary materials launched from airships, to put the world in position to profit by the application of Nobel's maxim.

Nor do gas and fire supply the last words. There are possible applications of electricity—artificial lightning, if the phrase be permitted—that will add new and terrifying elements of effectiveness to aerial warfare.

Nations, after all, are only aggregations of individuals, and a sane individual, except in a frenzy of anger, does not attack an enemy of twice his size and strength.

CAN SCIENCE BANISH WAR?

Suppose that in 1914 Germany had known that if she took up arms she would have immediately the armed opposition not only of France and Russia but of Eugland, Italy, America, Japan, and nearly a score of lesser nations. Suppose further that aircraft and poisonous gases and incendiary bombs had been developed to the stage at which they are to-day, and that Germany had been warned by a council of nations that if she made an aggressive move the total population of every one of her major cities would be blotted out of existence—would she have gone to war?

The question answers itself.

Make wider application of the same question. Reflect that in the near future oceans will be eliminated by the airship, and that tens of thousands of these craft will be in operation throughout the world. Reflect that it would be possible for a council of nations to serve notice upon any one of their number that is bent on unjust aggressions that all the others would unite forces against her and send, let us say, fifty thousand airships within a week to visit her cities with gas and fire—can the result be in doubt?

Under such circumstances, the vital interest of every civilian would be involved, and no nation would go to war without the full and tangible approval of its citizenship. This is equivalent to saying that no nation would go to war at all; as no popular ballot would declare for war under such circumstances. It is true that one can conceive an affront to national honor that would lead a population to declare for war even knowing that the result must be annihilation. But it is inconceivable that any council of conciliation representing all nations should impose such an alternative upon one of their number. An individual nation or a small group of nations, might make unjust claims against a fellow nation; but such claims would never be upheld by the majority of a council of nations whose personal interests were not involved.

If it be not possible to have an international council which would be dominated by justice in determining the larger questions of international relationship, then civilization is a myth.

Fortunately there is no need for solicitude on this score. It is universal observation that mankind loves justice in the abstract. So long as our own interests are not involved, and therefore our own prejudices developed, all of us would like to see right and justice prevail. And here again what applies to individuals applies to nations as well.

But it is useless to talk about adjudicating disputes without having power to enforce decisions. As Chief Justice Taft has so ably pointed out in his exposition of the principles of A League to Enforce Peace, it would seldom be necessary to

use force, just as it is seldom necessary for the policeman to use his club. The policeman does not need to use his club, because everyone knows that the force of organized society is back of him. With the force of organized nations of the world back of a League of Nations; supported by the knowledge that as a last resort, if driven to the extremity, this organization of nations can apply a power as irresistible relatively against any individual nation as the power of the police department is irresistible against a recreant individual—that knowledge will suffice.

But it is only through the development of airships, virtually eliminating international boundaries and making available new military methods, that it has become possible for even the greatest aggregation of nations to hold unquestioned superiority over a nation of the first class. Thanks to these developments, this condition now obtains, and thereby is the prophetic dream of Alfred Nobel brought at least one step nearer to realization.

CHAPTER II

A FEW LESSONS FROM THE WAR EXPERIENCE

HOWEVER ardently we may wish to forget the war, we can not get away from the fact that for four years the inventive genius of the world focussed on the destructive rather than the constructive industries. "How can I aid in killing men?" was the one universal question.

For four long years, then, all roads led to the war. But war, after all, is only a disease of the social organism; and it is a commonplace of medical science that diseased conditions evidence either increase, decrease, or perversion of normal functions. So it is not strange that we find the arts of war everywhere linked very closely with the arts of peace. It may be taken for granted that there is and will be no application of science, no new scientific discovery, in connection with the war that will not in the end redound advantageously to some peaceful industry.

As a tangible illustration, consider the new process of extracting nitrogen from the air. The process consists of mixing together carbon in some form (say coal-dust), carbonate of soda, and iron filings, and heating the mixture in a retort to a temperature of from 700 to 900 degrees Centigrade in the presence of nitrogen gas—that is to say, air freed of its oxygen. The iron filings act as a catalyzer, stimulating the sodium and carbon and nitrogen to unite for the formation of sodium

cyanid. When this is treated with steam the sodium is released, and the remainder of the product is transformed into ammonia. And ammonia is an agent utilized in the manufacture of high explosives. Our Government, when the war closed, was expending large sums of money to construct plants for the making of ammonia by this process. It is understood that Germany must early have given up the war through lack of explosives had not her men of science known how to extract nitrogen from the air.

It is of interest to recall that the process of nitrogen fixation just described was discovered about seventy years ago, but was not made commercially feasible until the past decade. A refinement of the methods, known as the Haber process, introduced in Germany, permits the use of purified nitrogen and hydrogen gases, with uranium for catalyst. The gases, heated to 1300 degrees Fahrenheit and under pressure of two hundred atmospheres, are passed over finely fragmented uranium, and they unite directly to form ammonia, NH_3. This may be united with oxygen to form the all-essential nitric acid by passing it, in heated mixture with air, through the meshes of a sieve made of fine platinum wire. Dr. Slosson, whose account I am following here, states that eighty-five per cent. of the gas is converted into nitric acid by catalysis even tho contact with the platinum lasts only a five-hundredth part of a second.

It should be noted that the development of this new process of extracting nitrogen had the utmost significance, not merely for the making of explosives to use in the World War, but for the farmer and the fruit-grower on one hand and for the

miner and the metallurgist on the other. The farmer finds nitrogen products absolutely essential for fertilization of his fields; the grower of oranges could not hope for half a crop were he unable to secure cyanids to "gas" his trees for the destruction of insects; and the miner could work only a small part of the ores that he now utilizes were he deprived of similar cyanids.

There are countless other uses for ammonia, cyanid, and other nitrogen products in the industries; but these illustrations will suffice to show how concretely the development of a war industry may benefit the arts of peace.

Of course the relationship is reciprocal. A large part of the applications of science in the war have grown out of discoveries made in laboratories having no martial purpose. We have already learned that dynamite itself, the type of high explosives, was invented by a man whose very soul revolted at the thought of war—the Swedish worker and dreamer, Nobel, known to all the world as the founder of the prizes that bear his name, for the establishment of which he left the entire fortune that he had acquired through the manufacture of explosives.

It will be recalled that one of the Nobel Prizes is for the production of idealistic literature and another for the work most tending to promote *peace*, the remaining prizes being for accomplishments in the fields of physics, chemistry, and physiology or medicine.

It may be correctly inferred from this that Nobel's genuine interest was in the use of high explosives as aids to the mechanical engineer, the miner, and the farmer rather than as warlike ac-

cessories. He sincerely believed that his discoveries would tend to decrease warfare, by making war so dangerous that nations would hesitate to undertake it. Unfortunately the developments of recent years do not sustain this hypothesis, but that detracts nothing from the merit of the discoverer of dynamite; tho we may well believe that had he forecast the uses that are now being made of high explosives he would have hesitated long before making his discovery known.

POISONOUS GASES

The poisonous gases of which we heard so much during the war constitute another illustration of the application to warfare of laboratory discoveries originally of quite different significance. Of course no one not associated with the military authorities knows the exact composition of the deadly gases even now, but we may fairly assume that there was nothing chemically mysterious about them in the beginning, however much they may have been modified in later months by one contestant or the other in the endeavor to secure a product difficult to evade or neutralize.

The familiar gas, chlorin, isolated and named by Sir Humphry Davy more than a century ago, was the basis of the gases first liberated in the trenches. It may be manufactured from common salt. Another familiar deadly gas is carbon monoxid, a combination of carbon and oxygen, only too familiar to the coal-miner, which is colorless and odorless, and heavy enough to pour into the trenches and displace the atmosphere. Even more deadly is hydrocyanic acid. This is a simple combination of hydrogen, nitrogen, and carbon; yet

it is the deadliest substance known to chemistry. A single whiff of it causes practically instant death. It may be produced in any quantity from the cyanid compound developed in the course of the above-described process of extracting nitrogen from the air.

No doubt ingenious methods of distributing the noxious gases were devised; but this is probably about the extent of invention in this direction, for chemistry is an old science, and enough has long been known about poisonous gases to serve all practical purposes. Phosgen, for example, to which Germany pinned their faith after chlorin attack ceased to be a novelty, is a well-known combination of carbonic oxid and chlorin ($COCl_2$). Fortunately the antidote was known (it is called hexamethylene tetramin), and the attack was met with gas masks soaked in this reagent.

Gas masks, considered as utensils of war, were of course a novelty, there having been no previous need of such a device. The basal material was usually charcoal, preferably made from a dense wood like coconut shell; supplemented by various chemicals to neutralize the poisonous fumes.

The ingenuity of chemists was exhausted in providing more and more nefarious compounds, in the hope of finding something that the mask could not stop. America's chief reliance was chlorpicrin (CCl_3NO_2), a compound of nitric acid and chloroform. The Germans ultimately produced vast quantities of what came to be dubbed "mustard gas," a complex chemical synthesized by combining chlorin, alcohol, and sulfur. The penetrating and persistent compound bears the alluring technical name of "di-chlor-di-ethyl-sulfid." This compound

was discovered by an Englishman (Guthrie) in 1860, and rediscovered by the German, Victor Meyer, in 1886. Phosgen had been known for more than a hundred years, having been discovered by John Davy.

These gases, then, were no novelties, and it does not appear, so far as the outside public is informed, that anything really new was invented in the course of the war, unless the tank be considered an exception. The mechanisms of destruction and defense—high explosives, shrapnel, explosive shells, hand-grenades, machine-guns, submarine boats, airplanes—were all in evidence before the war started, and the airplane was the only one of these that was relatively new at that time.

AMERICAN INVENTIONS

Curiously enough, Germany, the militant nation, had no conspicuous part in the development of any one of the destructive mechanisms. It is still more curious, perhaps, that America, a country assuredly without warlike ambitions, was chiefly responsible for inventing and developing the mechanisms that had the largest share in transforming warfare; namely, the telephone, the machine-gun, the steel ship, the submarine boat, and the airplane. Wireless telegraphy was perfected by an Italian, and the high explosives, as just mentioned, were made available by the discoveries of a Swede. Frenchmen and Englishmen were largely responsible for the invention of the gasoline engine which drives the submarine and the airplane; altho here, if anywhere, German inventors may claim a share of the credit. The gyroscopic stabilizer, which adds largely to the

safety of the airplane, was developed by an American.

And yet, when the war broke out, Germany was found in possession of the best submarines, the best airplanes, the best machine-guns, the largest cannon. She had adopted all the inventions of the other nations, and had developed and perfected them for her own purpose. She had the audacity to assume and declare that her borrowed science would win the war. She failed to realize, seemingly, that the nations that had invented the war-like mechanisms could surely learn to use them effectively once their attention was turned thereto.

"BIG BERTHA"

Doubtless the most spectacular novelty introduced by the Germans was the gun that bombarded Paris from a distance of seventy-six miles. But there is no reason to suppose that the construction or operation of this weapon involves any new or even novel scientific principles. Since the time of Galileo, the principles that govern the flight of projectiles have been well understood. A ball fired from a cannon drops sixteen feet toward the earth in the first second precisely as does a weight of any other kind under any other circumstances.

If you fire a horizontal cannon over the water, and drop a cannon-ball from the level of the muzzle simultaneously, the two balls will strike the water precisely at the same time. The distance traveled by the ball fired from the cannon will depend upon its initial speed and the resistance offered by the air.

If the barrel of the cannon is sixteen feet above

the water, and the velocity of the ball is a mile per second, the maximum range will be one mile. But the same cannon, when its barrel is tilted upward, using the same charge, may throw the projectile five miles or ten miles. Lengthen the barrel, increase the charge, and construct the projectile so that it offers a minimum of resistance to the air, and tilt the barrel of the cannon upward to an angle of something over forty degrees; and the projectile is sent hurtling to such an altitude that the rarefied air offers relatively little resistance, so that its speed slackens gradually, and it will take a long time in falling (going forward meantime) and thus extend the range almost indefinitely.

It is probable that the seventy-six mile cannon used a sub-caliber projectile with temporary flanges to fill out the relatively large bore. The relatively narrow projectile offered a minimum surface for air resistance; and it is estimated that it must have reached an altitude of something like twenty-four miles above the earth. The state of the atmosphere at this altitude is known only inferentially; but there can be no question that it is rarefied to an extent that renders its resistance almost negligible. From second to second the speed of the projectile lessened very little (in a perfect vacuum it would never change at all), and it accomplished an amazing journey before gravitation gained final mastery over it.

But in all this, as I have said, there is no new principle involved. By building a gun of relatively enormous size, and using a projectile relatively small, it was possible to shell Paris from a distance of seventy-six miles, with a

projectile that travels over a parabolic course of about one hundred and twenty miles. There is no reason to suppose that this represents a maximum possibility; a smaller projectile, propelled by the same force, would travel still farther. But the practical value of such a weapon must be very limited. The war was not won, nor was its termination particularly hastened, by devices of this character, altho it is not to be denied that the long-range gun is a very exasperating instrument.

THE GASOLINE ENGINE

Estimates as to what won the war depend a good deal on the point of views, so many doubtful factors are involved; but there are three outstanding mechanisms that were constantly reckoned with—the submarine boat, the airplane, and the fighting tank. There could not well be greater diversity of plan or function in these three mechanisms; yet all of them are actuated by the same apparatus, the gasoline engine. Some big tanks, to be sure, were driven by steam; but the vast majority of tanks were of a size adapted only for the other type of motor. Meantime it is obvious that the airplane could not have come into being until the gasoline engine was developed; and that the submarine is almost equally dependent upon the same type of motor. The submarine is of necessity equipped also with storage-batteries to propel it when it is actually submerged; but the storage-battery has a limited period of action, and will drive the submarine under water only about one hundred and forty miles; after which the craft must come to the surface and put its

oil engines in operation in order to recharge the batteries.

Science has done much to perfect the oil engine since the war started, as the most casual retrospect of the every-day feats of the airplane shows. No doubt strenuous efforts were made also to better the storage-battery, but little was accomplished in this line. The importance of the subject will be manifest when it is reflected that if the Germans had been able to perfect a craft that could navigate under water fifty per cent. farther than their actual ones were able to do, they could have made their way through the English Channel unobserved, and their predacious raids in the Atlantic would have been greatly facilitated.

From our own point of view, the scientific aspect of the submarine problem involve the development of (1) apparatus to detect the presence and determine the exact direction of the submarine when completely submerged; (2) new types of swift destroyers built so low as to be undetected through the submarine's periscope at a little distance; (3) depth bombs that exploded under water and crushed in the shell of the submarine; (4) cannon projectiles so constructed that they would dive when they struck the water instead of ricochetting; (5) nets to entangle the submarine after the fashion of primitive fishnets; and (6) ships so constructed as to be "unsinkable." But here again what was called for was the elaboration and modification of familiar scientific principles.

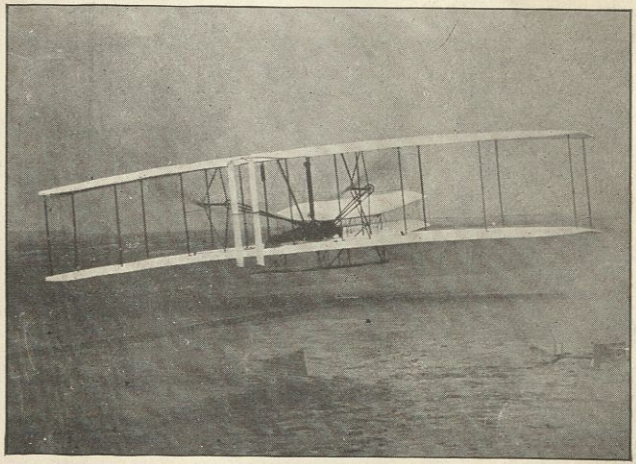
It is not to be overlooked, however, that it is through working along the lines of familiar prin-

ciples that new scientific discoveries are made. If perchance some brand-new things did develop in connection with the submarine offense or defense there are obvious reasons why they might not be known outside the narrow official circles even after the war.

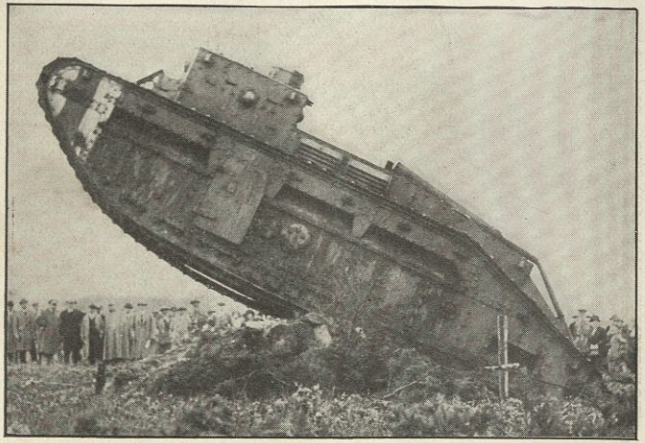
MEDICAL ACTIVITIES

There is, however, one field in which, for humanitarian reasons, there is no secrecy regarding new discoveries. This is the field of medicine. Here the outstanding event was the discovery of a method with which the names of Drs. Dakin and Carrel are associated, the essence of which is the irrigation of wounds with a solution of a chlorin salt for purposes of disinfection—that is to say, for the destruction of micro-organisms that might cause gangrene and blood-poisoning. This, of course, is only carrying out the principles established by Lister more than a third of a century ago, but the particular fluid devised by Dr. Dakin proves peculiarly effective in connection with the ingenious system of irrigation tubes devised by Dr. Carrel.

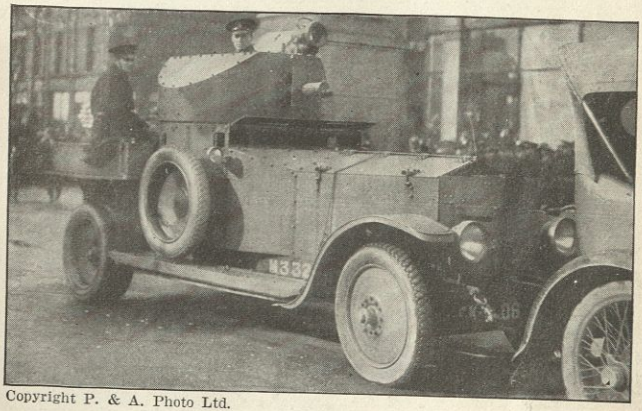
It is impossible to estimate more than vaguely the saving of life that resulted from the use of this new application of the antiseptic method. The figures are large but they must be overshadowed by another set of figures that tell of the protection given the soldiers against death from typhoid fever by the use of Sir Almroth Wright's anti-typhoid vaccine. In all antecedent wars since history began (with the unique exception of the Russo-Japanese War) there were from ten to twenty deaths from plagues, of which



THE ORIGINAL WRIGHT BIPLANE, THE FIRST SUCCESSFUL AIRPLANE; AND SIXTEEN PURSUIT PLANES IN BATTLE FORMATION



RECENT BRITISH WAR TANK GOING OVER A HURDLE AND SMASHING A TREE AT ALDERSHOT



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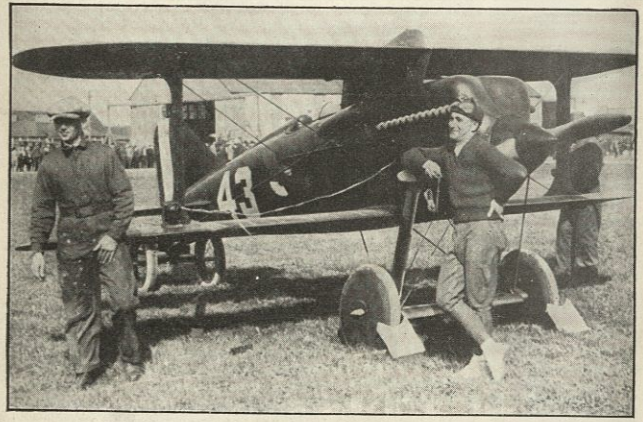
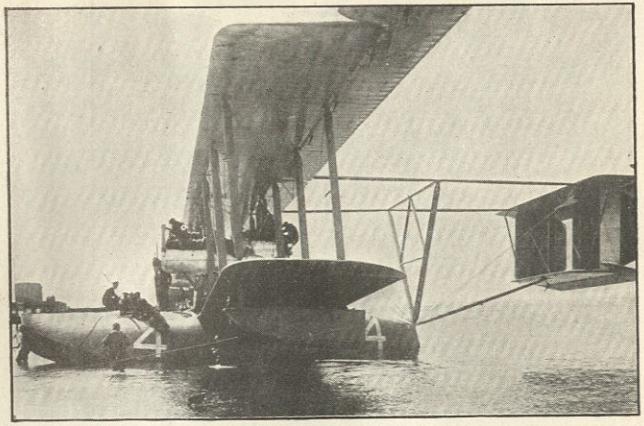
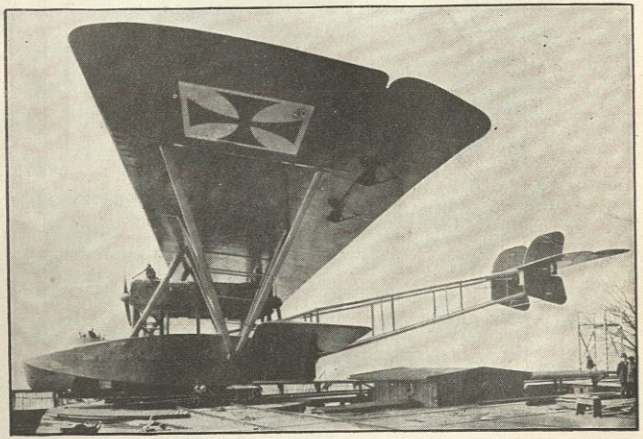
AN ARMORED CAR IN IRELAND (BELOW), AND THE CHRISTIE AMPHIBIOUS BATTLE TANK PROGRESSING ON LAND AFTER SWIMMING THE HUDSON RIVER



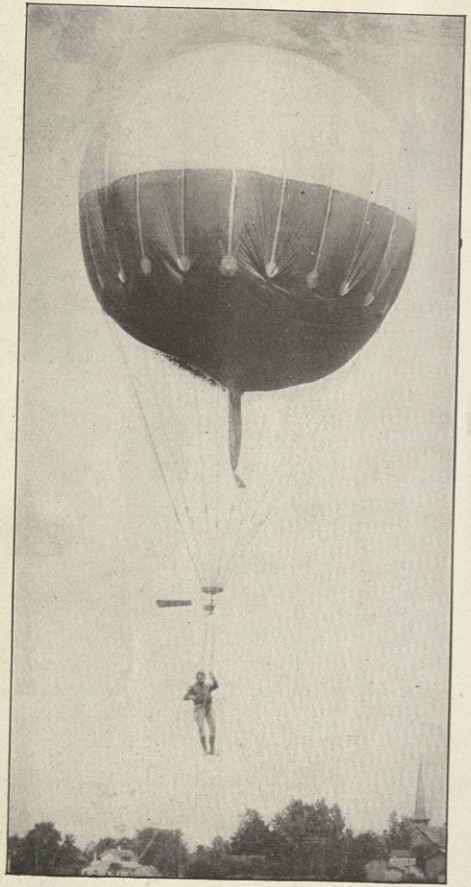
LIEUT. MAUGHAN AND THE CURTISS BIPLANE WITH WHICH HE WON THE PULITZER PRIZE AT DETROIT BY AVERAGING 206 MILES AN HOUR (BELOW), AND GENERAL WILLIAM E. MITCHELL ALIGHTING FROM A NEW CURTISS SCOUT PLANE



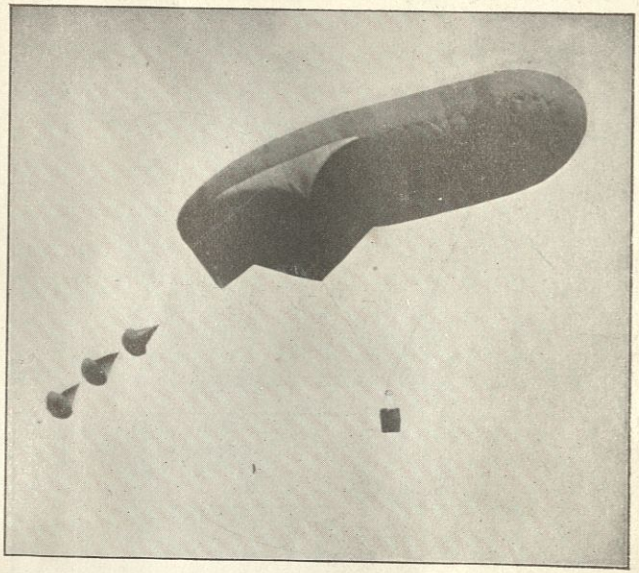


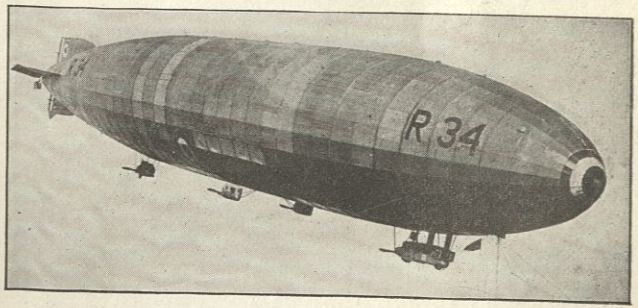
U. S. Army Air Service

DORNIER MONOPLANE FLYING BOAT OF 1916 (BELOW), AND N C-4, THE AMERICAN FLYING BOAT THAT CROSSED THE OCEAN IN 1919

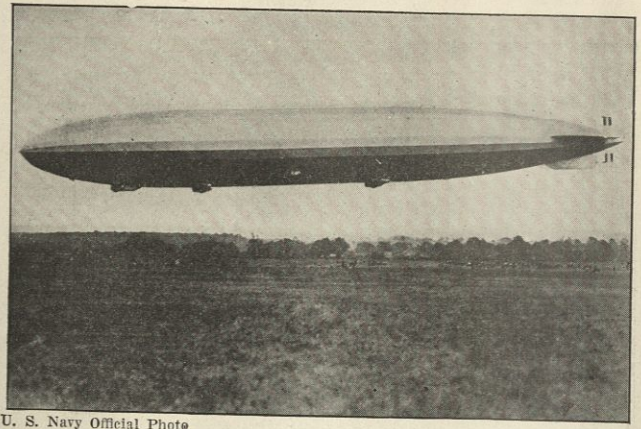


THE SMALLEST MAN-CARRYING BALLOON, DEVELOPED AT McCOOK FIELD, DAYTON, OHIO. IT IS BALANCED WITHIN FOUR POUNDS BY SAND BALLAST, AND THE PROPELLER IS OPERATED BY HAND

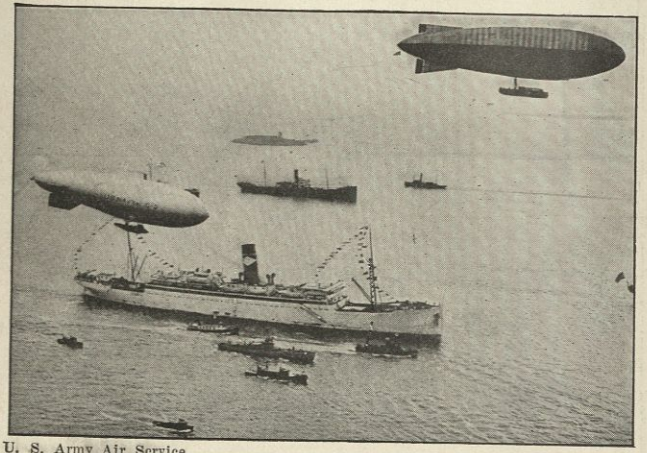




AN ARMY DIRIGIBLE (BELOW), AND A CAPTIVE OBSERVATION BALLOON



U. S. Navy Official Photo



U. S. Army Air Service

PRESIDENT HARDING ARRIVES AT NEWPORT NEWS WITH ARMY AIR ESCORT (BELOW), AND Z R-1. THE WORLD'S LARGEST DIRIGIBLE AS SHE WILL LOOK WHEN SHE STARTS ON THE PROJECTED WORLD CRUISE AND FLIGHT TO THE POLES

typhoid fever is perhaps the chief, to one death from bullets. In the "World War" deaths from typhoid fever were negligible. The anti-typhoid vaccine was used experimentally in the Boer War, but this was the first opportunity to test it on a comprehensive scale. It stood the test; and the historian of the future will record as perhaps the most marvelous scientific achievement in connection with the entire war the banishment of this plague by the hypodermic needle of the physician.

THE AIRPLANE REVOLUTIONIZES TACTICS

For the military historian, interest in the future will doubtless center on the modification in tactics, strategy, and land warfare in general made necessary by the advent of the airplane. How radical the modifications have been no one to-day needs to be told. Nor need the shortest memory be jogged to recall the time when the mechanism which has effected this revolution had no existence except in the minds of men who were regarded as hopeless visionaries.

Less than eleven years had elapsed, when the war broke out, since the Wright brothers made the first flight that refuted the calculations of the skeptics (1903). Five years later the Englishman, Henry Farman, astonished the world, and incidentally won a $10,000 prize, by flying in a prescribed circle, covering about 1600 yards, and alighting at the starting point. The flight was made in France, with a machine based essentially on the Wright Brothers' discoveries. In the same year (1908), Orville Wright made spectacular demonstrations at Fort Myer, the most remarkable of which consisted in flying con-

tinuously in a circular course for an hour and fifteen minutes; and it was not until July 27, 1909, that Mr. Wright successfully met the conditions of the endurance test by flying more than an hour carrying a passenger.

Three days later he completed the tests by flying across country a distance of five miles and return—and the news was flashed around the world as the record of an astounding feat.

Even after it had been demonstrated, in 1908, that by skilful piloting it is possible to keep a flying-machine in the air continuously for over an hour, it would have seemed utterly foolhardy to predict that this machine would within six years revolutionize warfare. But the facts now are matters of history, and the same men who, prior to 1908, utterly disbelieved that it would ever be possible for a heavier-than-air machine to leave the ground directed by a passenger, six years later pinned their faith to the airplane as the mechanism that would determine the outcome of the World War.

We have but to recall that when the war was under way the military program involved the production of airplanes by tens of thousands, to gain a realizing sense of the importance of the work accomplished by Wilbur and Orville Wright when they invented the heavier-than-air flying machine. Their accomplishment will be remembered among the outstanding events of world history long after the "World War" has become only a vague reminiscence.

CHAPTER III

MODERN EXPLOSIVES

IF YOUR memory reaches back to details of what seems a prehistoric epoch, you may recall that the most surprising developments of the early weeks of the Great War in Europe in the autumn of 1914 were associated with the quick fall of the forts and fortified cities before the German siege guns.

The forts of Namur had been supposed to be almost impregnable; and the fortifications of Antwerp were by many military authorities regarded as beyond the reach of any destructive mechanisms that could be brought against them. At the very least, it was supposed that Antwerp would hold out for weeks or months against the invaders. Yet when the great siege guns were leveled against it, their missiles proved so utterly destructive that the capitulation of the devastated fortress was a matter of days—almost of hours.

It would appear that nothing as yet devised by human ingenuity in the way of defensive fortifications can withstand the terrific blasts of such explosives as the siege guns dropped upon the ramparts from their safe coign of vantage, miles away.

Of course, the precise range of the fortifications was known to the German gunners, and they could place their shells with unerring accuracy; whereas the range finders in the fortress were probably unable to locate the attacking bat-

teries with any degree of accuracy before their weapons were put out of commission. In the matter of accurate placing of shots, the masked battery temporarily located in trench or ravine, or behind hill or building at a distance of many miles, had an infinite advantage.

It was reported that some of the German siege guns were of sixteen-inch (forty-two-centimeter) caliber—doubtless the largest field weapons ever carried in a campaign into an enemy's country. These monster weapons were of howitzer type—in effect, lengthened mortars. As compared with ordinary cannon, they were relatively short; but even so, their weight was enormous, their transportation being effected by powerful motors. The coming of the automobile had encouraged the development of good roads; and now automobiles were everywhere utilized for the transportation of troops and weapons and general supplies, making possible the maneuvering of large bodies of troops with a rapidity and facility hitherto without precedent.

When the invading hosts camped before a fortified place, therefore, they were not necessarily at a disadvantage as to power of armament. Their siege guns equaled or excelled in caliber and in range the guns of the forts themselves, so that even if the attacking batteries had been susceptible of being readily located from the forts, they might still have carried on the duel on almost equal terms. For the earth mounds and walls and steel casements of the fortress afforded scant protection against the modern projectiles, once the range had been accurately gaged.

When a modern explosive is detonated it destroys whatever is in its vicinity, regardless of whether the structures be of earth, of concrete, of wood, or of steel.

The government chemists of all nations had been constantly engaged in the endeavor to perfect new types of practical explosives. It was apparent that the efforts of the German chemists had been at least as successful as those of any other company of experts; for the explosive shells that reduced the forts of Liège and Namur and Antwerp, the torpedoes that sank the *Aboukir* and *Hogue* and *Cressy* in rapid succession, and the mines that sank the *Audacious* performed their respective tasks in a way that left little to be desired from the standpoint of their designers. And these things were only the beginning of what went on for four dreadful years.

If wet gun cotton and dynamite, as employed in the torpedoes and mines of the Russo-Japanese War, had seemed to lack something of complete effectiveness, no such criticism could be passed upon the new explosives that actuated the agents of destruction employed in the Great European War of 1914-1918.

The precise composition and methods of manufacture of explosives employed by each government are of course carefully guarded military secrets. It soon became an open secret, however, that the chief explosive used by the German military authorities in their shells, torpedoes, and sea mines was a compound known as trinitrotoluene, a coal-tar derivative of comparatively recent invention, which was usually referred to by British

military experts as "T. N. T." and by Germans as "Trotyl."

T. N. T. is made by treating the coal-tar product toluol with nitric acid. It melts below the boiling point of water, is resistant to ordinary concussion, and burns quietly if lighted—almost ideal qualities.

It must not be supposed, however, that this new explosive is necessarily superior to the explosives used by other military powers, altho it had advantages over the explosives in use only a few years earlier. Nor must it be inferred that trotyl and the other new explosives are more powerful than any others hitherto known, as the layman might not unnaturally suppose.

In point of fact, there are substances known to the chemist that explode with greater violence than is manifested by any compound used in the construction of military explosives or propellants. The power of an explosive depends upon its capacity to produce a large volume of gas from a comparatively small amount of original solid matter. Judged by this standard, the most powerful explosive known is probably a salt of hydrazoic acid (N_3H), the ammonia compound of which (N_3NH_4) produces, according to the French chemist Berthelot, one thousand one hundred and forty-eight cubic centimeters of gases (at atmospheric pressure) for one gram weight of substance. No other known substance gives a corresponding change of volume in passing from the solid to the gaseous state.

But these compounds of hydrazoic acid explode with extreme violence if heated to a temperature

only slightly above the normal boiling point of water.

They are therefore far too sensitive to be used for the practical purpose to which military explosives are put. Moreover, their extreme violence of action would be to some extent a disadvantage. It would prevent their use as propellants, since they would burst the gun barrel; and if placed in torpedoes or mines they would shatter their inclosing cases almost to the condition of powder on being discharged, and on the whole would thus have a less destructive effect than would be produced by an explosive that burst the shell into relatively large pieces and, by relatively slow combustion, extended the area of its destructive influence.

Such tendency to overrapid explosion is a fault of picric acid and its derivative lyddite (or as the French call it, melinite), which is another coal-tar derivative, made by treating phenol (carbolic acid) with the inevitable nitric acid and sulfuric acid. And, in general, it may be said that the practical explosives now used in warfare are modified in such a way as to retard rather than to accelerate their rapidity of action when detonated.

Moreover, they are modified in different ways to meet different needs. For example, the British explosive, cordite (a compound of nitroglycerin and nitrocellulose), which is used for small arms and for cannon alike, is modified in action by the simple expedient of manufacturing it into "cords"—whence its name—of smaller or larger size. The larger the cord, the slower its combustion. Thus it may be adopted to the

requirements of a relatively slow-burning propellant or of a quickly detonating explosive—altho for practical purposes lyddite is substituted in mines and torpedoes. Cordite (nitroglycerin and nitrocellulose), lyddite (carbolic acid plus nitric and sulfuric acids), and trinitrotoluol (toluol treated with nitric acid, and called T. N. T. for short) are the three types of modern explosives that dominated the war situation. All have enormous efficiency as compared with old-fashioned gunpowder.

All this will perhaps be somewhat more clearly understood if we consider in detail the nature of explosions in general and the principles that govern the action of explosives.

HOW EXPLOSIVES ACT

An interesting elementary experiment may be made by scattering a pinch of lycopodium powder (which may be obtained at any drug store) in the air and striking a match. The almost invisible particles of powder—in reality they are pollen grains—will ignite with explosive suddenness, producing a miniature conflagration in the air that is distinctly startling.

The same phenomenon is manifested on a large scale when an explosion occurs in a coal mine. Such an explosion may result from coal dust floating in the air or lightly sprinkled about the corridors of a mine. The results are often highly disastrous.

The explanation of the phenomenon, with either coal dust or lycopodium powder, is merely that the combustible matter exists in the form of excessively minute particles surrounded on all sides

by air. If the same particles were brought together and compressed into a solid mass, relatively few of them would be in contact with the air, and when the mass is ignited combustion would take place slowly—as witness the slow burning of a lump of coal.

Now this difference between the rapid burning of the particles of coal dust when scattered through the air and the slow burning of the same particles when massed into a lump of coal is precisely the essential difference between explosion and ordinary combustion. In each case the chemical phenomenon involved is the union of the atoms of carbon, which are the chief constituents of coal, with the atoms of oxygen. In each case the result is the production of gases, chiefly carbon monoxid (CO) and carbon dioxid (CO_2). In each case the gases thus formed, obeying the nature of gases, expand with violence under influence of the heat that the chemical reaction generates.

And the only reason why we have in one case an "explosion" and in the other a simple "combustion" or burning is that in one case a large number of particles are burned simultaneously and hence a large quantity of gas produced too quickly to escape without damaging the chamber in which the burning takes place.

When coal is burned in a grate or stove, an air current constantly blows the combustion gases away and carries them up the chimney. If, however, the coal were burned, however slowly, in an air-tight chamber, the walls of which were so constructed as to prevent the escape of heat, the gases formed would presently exert a pressure

that would rupture the walls in a manner precisely equivalent to an explosion.

An all too familiar illustration of the difference between burning a combustible substance in the open and in a closed receptacle is furnished by the accidental explosion of gas ovens, resulting from turning on the gas too freely and igniting while the oven door is closed. But for that matter it is well known that even such an explosive as gunpowder may be safely enough burned in the open.

Yet the same quantity of powder if ignited in a closed chamber would produce a violent explosion.

The reason why the powder burns slowly in the open is that the heat produced is dissipated, so that the entire mass of powder is not rapidly raised to a high temperature. There is the closest association between high temperatures and the explosive activities of a gas, as will be explained more at length in a moment.

GUNPOWDER AND HIGH EXPLOSIVES

The essential principle on which the action of gunpowder and other manufactured explosives is based is simply that the compound shall contain within its own substance (1) one or more nitrogen atoms, and (2) enough oxygen to effect the combustion of the other substances making up the compound.

Ordinary gunpowder, for example, which for some centuries was the only practical explosive known, consists of about seventy-five parts nitrate of potash, or saltpeter, intimately mixed (not chemically combined) with about fifteen parts of gunpowder charcoal and ten parts of powdered

sulfur. Saltpeter is an unstable compound of potassium, nitrogen, and oxygen. Each molecule contains one atom of hydrogen, one of nitrogen, and three atoms of oxygen (KNO_3).

The presence of the nitrogen atom makes the molecule of saltpeter very unstable. For the nitrogen atom is essentially patrician. It seems to care for the society only of its own fellows. When forced into combinations with other atoms it has a strong innate propensity to liberate itself from the entangling alliance.

So the molecule of saltpeter may be thought of as a community that is always on the verge of disruption. Or it might be likened to a coiled spring held in place and ready to fly into action the moment the restraining force is released.

Notwithstanding the innate restlessness of its nitrogen component, the molecule of saltpeter, once formed, is powerless to change its condition unless the initiative comes in the form of some outside disturbance, so the gunpowder, of which it forms the chief part, is as inert and harmless as so much dirt, unless a disturbing influence is brought to bear on it. Suppose, however, that a spark of fire comes in contact with the powder. The heat so increases the activities of the molecule as to enable its particles to break loose from their unwilling bonds.

In effect the spring is released.

Instantly the nitrogen atom dashes out in one direction, the oxygen atom in another. Heat is liberated, and contiguous molecules are similarly disturbed. Each nitrogen atom unites with a fellow atom to produce nitrogen gas. The oxygen atoms combine eagerly with the atoms of carbon

supplied by the charcoal, producing carbonic acid gas and carbon monoxid. Some potassium atoms combine with oxygen; others are left to themselves. To supply their needs the sulfur was provided, for these two have an eager liking for each other.

So the mixture that was potassium nitrate (KNO_3) and carbon (C) and sulphur (S) has now become carbon monoxid (CO) and nitrogen gas (N_2) and carbonic acid gas (CO_2) and potassium sulfur (K_2S) and potassium oxid (K_2O) and potassium carbonate (K_2CO_3). The potassium salts, representing more than half the bulk of the original mass of the explosive, remain as an inert powder and are made visible in the form of smoke.

There are some complexities of the reaction that concern only the chemist. But the essential thing is that nearly half the substance of the powder has been converted into gases, which now, superheated in the process of transformation, press with terrific force in every direction in their efforts to escape. Unless afforded instant exit (as by discharge of a bullet) they disrupt the walls that contain them, producing a more or less violent explosion.

The more modern types of explosives operate in precisely the same way, but owe their greater violence of action to the fact that they are made up of still more complex molecules, the entire substance of which is converted into gases. There being no inert metallic residue, such as that formed by potassium and sulfur, these "high" explosives are relatively smokeless.

The type substance which is the basis of dyna-

mite and of the important cordite is nitroglycerin, which is a very complex compound of carbon, hydrogen, nitrogen, and oxygen, the formula usually given being $C_3H_5N_3O_9$. It is made by treating gylcerin with nitric acid.

When this molecule is disrupted, nitrogen is set free as before, and the liberated oxygen atoms combine on one hand with carbon to form carbonic gas, and on the other with hydrogen to form water, which at the high temperature involved has the form of a truly gaseous vapor. The amount of heat liberated is relatively enormous, and there is no non-combustible residue.

Dynamite owes its explosive power entirely to nitroglycerin, which is incorporated with some suitable absorbent. Gun cotton, made by treating cotton fiber or other vegetable tissues with nitric acid (therefore called nitro-cellulose), is closely similar to nitroglycerin. We have seen that the two are mixed to make cordite. Picric acid, the foundation of lyddite, is a coal-tar derivative of the same general formula as the other high explosives. Its basis, as already noted, is carbolic acid.

All these explosives depend on unstable nitrogen compounds that were built up originally through the action of living tissues.

Some conception of the energy stored in these unstable compounds may be gained from an estimate of the French chemist, Berthelot, according to whose tests the explosion of gunpowder may produce a pressure of twenty-four thousand atmospheres; that is to say, one hundred and sixty tons to the square inch.

THE POWER OF NUMBERS

Most readers are probably aware that the expansive property which characterizes gases, and upon which the effect of all explosives depends, is due to the activities of the molecules that make up the gas. The molecules are unthinkably but not immeasurably small. The number of molecules in a cubic millimeter (one-twenty-fifth of an inch) reaches a figure that requires for its expression a unit followed by sixteen ciphers—that is to say, that runs into quintillions.

Even the newly found "rare" gases of the atmosphere, of which only a "trace" is said to exist, are really represented by enormous numbers of molecules. There are, for example, about four hundred billion atoms of neon and about forty billion atoms of helium in each cubic millimeter of dry air at normal temperature. Yet these numbers constitute such an infinitesimal company, as compared with the huge galaxies of nitrogen and oxygen atoms, that chemists have only recently detected their existence.

These figures give some faint conception of the minute size of the molecules, but in so doing serve to make the enormous energies exerted by these molecules the more mysterious. To explain the colossal power which the molecules are observed to exert, as when a bit of dynamite is exploded, it is necessary to recall that each and every molecule is an elastic body which is incessantly in motion, colliding with its fellows and bounding away as if possessed of an insatiate desire to find isolation.

It is estimated that each molecule collides with

another molecule on the average about six billion times per second.

Whoever cares to multiply that number by about forty quintillions (the number of molecules in a cubic millimeter) will set down in figures the number of collisions that take place each second in every millimeter of a gas at ordinary temperature.

The number, as will appear, is represented by two hundred and forty followed by thirty ciphers. In words, it is two hundred and forty millions of billions of billions; otherwise two hundred and forty *nonillions*.

This inconceivable number of times per second, then, the molecules collide with one another in each cubic millimeter of the air we breathe, or of any other gas; and after collision spring back, like rubber balls, against any obstructing surface. Each individual push is infinitesimal beyond computation; but sundry billions of the pushes combined make an impulse that will burst barriers of steel. Reflect that the molecules become vastly more resilient and active with increased temperature, and the full action of the explosive is at least proximally explained.

Where else could one find a comparable object-lesson in the overwhelming power of numbers?

MODERN SUBSTITUTES FOR GUNPOWDER

A practical gage of the energy involved in the combustion of an explosive is furnished by the extraordinary temperatures produced. Thus a mixture of the metal aluminum granulated and oxid of iron, when ignited by a fulminating powder, readjusts these atoms to form oxid of alumi-

num and pure iron, and does this with such fervor that a temperature of about three thousand degrees is reached.

This is a temperature far in excess of that which may be obtained with ordinary fuels in the blast furnace, the maximum of which is about one thousand and eighty degrees; altho it does not quite equal the three thousand six hundred degrees Centrigade of the electric arc.

Even this temperature is exceeded, however, in the explosion of cordite in closed steel chambers. In the experiments of Sir Andrew Noble and Sir S. Abel, in which cordite was thus exploded, it was estimated that the temperature approximated five thousand degrees Centigrade. At a far lower temperature than this iron is not only melted, but brought almost to the boiling point; the temperature attained by the exploding of cordite in a closed chamber must bring the metal almost to the point of vaporization.

Cordite, as already explained, is a form of smokeless powder used in the British army. It is composed of gun cotton, nitroglycerin, and mineral jelly.

Needless to say, it is not desirable to attain such temperatures in the use of cordite as a propellant. But the extreme heat produced is associated with the suddenness of the reaction; and it has already been explained that in practise this is controlled by the form in which the cordite is prepared. It obviously would not do to produce a temperature of five thousand degrees within a gun barrel, as the metal itself would thereby be liquefied or even vaporized; but by regulating the size of the filaments in which the cordite is made

it is possible so to retard the combustion that heat production is regulated and adjusted to the needs of the particular weapon, the energy liberated being used to propel the bullet without material injury to the gun barrel.

What is true of cordite is equally true of other forms of smokeless powder, all of which have the same essential constitution; their peculiarity, as already explained, consisting merely in the fact that their entire substance is susceptible of being transformed into the gaseous condition. One of the first problems that confronted the inventor when the idea of using high explosives of this character as propellants was conceived was to regulate the rate of explosion. A solution was found in the reduction of the explosive substance to a powder of varying degrees of granulation. Such an explosive as cordite burns from without inward, and its rapidity of combustion is determined by the size of the granules or particles. In this regard it does not differ essentially from coal, which, as we have seen, is explosive when reduced to a fine powder, yet burns slowly when in the form of nuggets.

When it is intended to use smokeless powder in heavy ordnance the substance may be prepared in cubes or blocks of different sizes, perforated with holes of varying size to regulate the surface exposure. In this way the same thing is accomplished that is accomplished with cordite when that substance is made in "cords" of varying sizes, from minute threadlike filaments to relatively large ropes.

Of course, when the explosive is to be used in a torpedo or mine, it may be desirable to utilize

it in such mechanical form or in such chemical combination that it will operate far more suddenly than would be permissible when it is used as a propellant. But even here, as has already been pointed out, it is not always desirable to produce the most rapid explosion possible. In the case of the shells used in land warfare, for example, it is better to have large fragments scattered widely, rather than to have a shower of minute splinters which operate within a small radius—better, that is to say, from the standpoint of the military tactician, whose essential purpose is, necessarily, the crippling or killing of as large a number as possible of the enemy's forces. And to produce this effect a comparatively slow explosion is more effective than an exceedingly rapid one.

Similarly, in case of a mine or torpedo, the explosive that acts with extreme rapidity may pulverize everything in the immediate vicinity, and in so doing needlessly exhaust energy that might more advantageously be utilized in the less complete but equally effective demolition of more distant objects.

It is obviously desirable that the explosives to be used in warfare as propellants, or in the construction of torpedoes or mines, should not be unduly sensitive to concussion. Everyone knows that ordinary powder may be rubbed or shaken or even struck with a hammer without danger of explosion. The higher explosives that have supplanted powder are, many of them, almost equally unresponsive. Dr. Slosson tells us that the girls working in cordite factories use pieces of cordite

as chewing gum. He states also that a rifle ball may be fired into a case of T. N. T. without exploding it. It is necessary, therefore, with the modern propellants, as with black powder, to use a so-called fulminate to detonate or explode the charge.

The first fulminate was discovered just at the close of the eighteenth century, and led very soon to the invention of the percussion cap. The fulminate in question was discovered by Howard, and was a product of the action of alcohol on a solution of mercury in nitric acid. Other fulminates have since been made, but the fulminate of mercury retains its place as the most practical and effective of detonants.

This substance is a compound in which mercury is united with carbon, nitrogen, and oxygen. It is a white crystalline solid, very sensitive to friction or percussion. Curiously enough, its rate of burning is too high to allow it time to ignite common powder; so it is mixed with certain quantities of inert substances, such as glass powder, which reduce the rate of burning. There is a metallic residue when the fulminate is exploded, but this, of course, is of no consequence, as the amount of the substance used to detonate a charge of powder or other explosive is infinitesimal. A minute detonating spark suffices to start the essential conflagration in the powder chamber.

It will be evident from what has just been said that there is no essential difference between the metallic fulminates and other explosives, as regards their principle of action. The value of the fulminates hinges on the fact that they ignite at

a low temperature, such as that produced by the concussion of a gun hammer or a similar impact.

THE EFFECTS OF HIGH EXPLOSIVES

In considering the effects of explosives it should always be recalled that an expanding gas presses equally in all directions.

The practical effect produced by an explosive depends, therefore, very largely upon the nature of the wall in which it is encased. Persons unfamiliar with physical laws often remark that dynamite exerts its force downward because it is observed to tear up the earth when exploded at the earth's surface. But, of course, this impression is altogether mistaken. Dynamite thus discharged, like any other explosive, presses equally in all directions, but the suddenness of the explosion causes it to tear up the earth at the same time that it is sending volumes of gases laterally and upward into the atmosphere.

When a mine explodes against the side of a ship its expanding gases press outward against the water quite as forcibly as against the hull of the vessel. But water is a practically incompressible fluid, far more unyielding than any mass of steel with which the ship's hull can be encased; so the effective expansion of the gas occurs largely in the direction of the vessel, shattering its hull. (We shall see this practically demonstrated in the airplane-versus-battleship bombing tests described in another chapter.)

When the explosive is ignited within a gun barrel it presses laterally and breechwise just as powerfully as it presses against the bullet. The only reason why the bullet goes forward while

the gun remains relatively stationary is that the bullet is smaller than the gun and less firmly anchored.

When the explosive projectile is detonated it of course operates on the same principle. If its shell is of uniform thickness throughout, its destructive effects will be manifest with equal force in every direction. The radius of its destructive action will be determined, as already explained, by the force of the charge itself and by the size of the fragments into which the shell is disrupted.

The changes in military tactics made necessary by the all-prevailing use of high explosives, both as propellants, to give great range to the projectile, and as disrupters of the projectile itself, when this is fired from ordnance (the use of explosive bullets in small arms being expressly prohibited by international agreement), was more forcibly illustrated in the great European conflict than ever before. In advancing, the armies departed as widely as possible from the old "close formation"; they were forced to take advantage of every protective feature of the landscape to escape annihilation by machine guns and explosive shells; and whenever their progress was retarded, they at once began digging elaborate systems of trenches on a scale never hitherto practised in either ancient or modern warfare.

The short-handled spade used for this purpose was invented, it may be noted, by an American engineer, Brigadier General H. W. Benham, of the Army of the Potomac, and was first used in our own Civil War. But its adoption, in one form or another, as a part of the regular equipment of the soldier is a matter of recent history. In the

recent war the short, steel-bladed spade played a part scarcely subordinate to that of machine gun and cannon.

Where the field was stubbornly contested, series of trenches were dug, each trench about four feet wide and five feet deep, the successive trenches being placed parallel to each other, and at right angles to the line of advance or retreat, at intervals of about a hundred yards, connection between them being effected by zigzag trenches, so that retreat or advance could be made under cover.

Wherever possible the trenches were themselves covered over in such a way as to shield their occupants from aerial bombs or the fragments of shells exploding overhead. In some cases concrete was used to give further effectiveness to the barricades, so that the intrenchments partook of the character of permanent fortifications.

In digging the trenches care was taken to scatter the earth widely, so that there might be no conspicuous object visible from a distance to serve the enemy in range finding.

All this was a tribute to the effectiveness of the modern weapon, which so changed the aspect of warfare that measures of protection that would once have been thought to savor of timidity or over-cautiousness were now matters of sheer necessity if the total annihilation of entire regiments or corps by machine guns and ordnance operating at long range was to be avoided.

WHY DO EXPLOSIVES EXPLODE?

If we seek to get beyond the mere how of the molecular activities which we have visualized as the "cause" of the explosion, we find ourselves

somewhat in the position of a colored man working in a garage who, in response to an inquiry from a former employer, declared himself to be nearly a full-fledged chauffeur, knowing pretty much all there is to know about an automobile, except that he couldn't "jess make out how that thar machine runs without any hosses hitched to it."

We smile at the negro's naïveté. Yet a good many of us, doubtless, would find it difficult to give a really satisfactory explanation of the familiar phenomenon that puzzled him. Every one knows, of course, that gasoline is fed through a carbureter into a cylinder and exploded there, driving back a piston which gives the thrust that turns the wheels. But just what is an "explosion"?

What happened that enabled the gasoline—which a moment ago seemed quite inert—to give this gigantic thrust? Why was this substance at one moment content to rest in an ordinary tank, and at a subsequent moment so eager to escape that walls of steel are required to hold it? Just why does it suddenly expand with such force as to turn the wheels of the automobile and drive it forward "without any hosses hitched to it"?

Because a spark has ignited it, you say. But does that explanation really explain anything? Why does igniting the gasoline give this sudden capacity to exert tremendous energy?

If we can not answer that question we do not really know how the automobile operates. But fortunately science is able to give at least a proximal answer. Long before the automobile itself came into existence, the theory of action of

gases was well established. Nothing fundamentally new has been added to it in recent years, but the subject has come to have a far larger measure of popular interest than ever before because of the application of the gas engine, not alone to the automobile but to the airplane and the submarine; and also because the same principles are involved in the operation of all explosives in the varied instruments of destruction of present-day warfare.

The principle in question is an exceedingly simple one. Reduced to its elements, it amounts to nothing more than saying that when two elastic bodies come in contact they exert a mutual thrust that tends to make them spring apart again; and that, the harder the original thrust, the stronger the reaction.

You may illustrate the principle perfectly with ordinary billiard balls. Watch any game of pool or pocket billiards. The balls are first clustered together to form a triangle. The player who makes the "break" applies a certain force to the cue ball; the force is transmitted to the other balls, and unless the original stroke was very light indeed, these will be scattered in all directions. As they come to the cushions, they will spring back, and if two of them come in contact they will bound away from each other again.

The harder the original impact, the wider the scattering of the balls, and the greater the vigor with which they will spring back from the cushions or from each other on mutual contact. And the whole thing is so simple and familiar that it appears to require no explanation at all.

The Newtonian principle that bodies set in motion move in straight lines unless some force deflects them, and that action and reaction are equal and in opposite directions—these fundamentals of mechanics explain the movements of the billiard balls adequately. And the same simple principles explain the activities of the molecules whose aggregate action constitutes an explosion, be it of gasoline in the automobile cylinder, of gunpowder in a rifle barrel, or of dynamite or its equivalent in hand grenade, cannon ball, or torpedo.

The molecules of the explosives are like miniature billiard balls, having a high degree of inherent elasticity, which impinge against one another, bound back, and by virtue of their mutual repulsion push in all directions against any receptacle in which they are contained. The aggregate force of the thrust thus given depends entirely upon the number of the molecules and the average speed of their flight. A billiard-ball or a molecule moving slowly impinges lightly against one of its fellows, and springs back with corresponding languor. A billiard-ball or a molecule moving rapidly impinges hard against its fellow, and springs back with corresponding vigor.

The molecules in any substance are unthinkably numerous,—a molecule being by definition the smallest ultimate physical particle of matter. Every substance is thus a potential explosive. The only problem is how to set its particles actively in motion.

A practical method of doing this, in the case of the substance called gasoline, is to apply a spark of fire. But what is fire? Unless we can answer that question we are again at an *impasse*. Fortunately the answer is not difficult. Fire, in the

present sense, is the phenomenon that results when atoms of oxygen unite very rapidly with atoms of some other substance. Owing to the force of impact, the molecules are in a state of violent vibration; and the proof of this is found in the observed phenomena of heat and light—heat being merely a manifestation of molecular activities; otherwise defined as a mode of motion.

All this is in effect a recapituation of what we have elsewhere learned. But in the interest of more complete understanding of a rather abstruse subject, let us continue.

The spark of fire, then, consists merely of a relatively small group of molecules that are in rapid motion; they transmit their motion to molecules with which they come in contact, and the disturbance passes on from one molecule to another until it involves all the molecules in the entire receptacle.

Only an infinitesimal moment of time is required for this, because the molecules are moving with inconceivable rapidity. Even under ordinary conditions, each molecule in a gas, it has been estimated, collides with another molecule about six billion times per second. The total number of collisions in a space the size of a pinhead is measured in unthinkable numbers which if written out would call for the use of thirty figures. The aggregate push that would be given by a mere million or billion molecules would be utterly insignificant; but when multiplication goes forward by decillions the aggregate becomes something enormous. The numberless billions of little pushes make an impulse that will burst barriers of steel.

If there are no encumbering walls, so that the molecules are at liberty to fly out in every direction, gas undergoes what we term expansion; the average distance between the molecules constantly increases, the collisions are less frequent, and, stated in practical terms, the temperature of the gas decreases. But if, on the other hand, there is no opportunity to escape, or if the imprisoned molecules are crowded closer together (by the piston of an automobile engine, for example), collisions occur more and more frequently, and the temperature rises in evidence of the increasing activities of the molecules.

Ultimately the activities may become so great that the aggregate outward pressure exceeds the resisting power of any receptacle that human ingenuity can devise.

So it is, for example, with the explosives in a cannon. The powder is ignited at one point by a spark, and the violent commotion among the molecules spreads to other parts of the powder chamber until all the molecular activities are so great that the substance becomes a gas—the sole difference between a solid and a gas being that the molecules of one are relatively quiescent and those of the other relatively active. Instant opportunity must be given for the gas to expand; otherwise the barrel of the cannon would burst.

There is, of course, a great difference among different substances in the ease with which their molecules may be set dancing; or, stated otherwise, in the amount of energy required to overcome the cohesive forces that hold the molecules together. It results, fortunately for us, that under the same conditions one group of molecules may

remain in the so-called solid condition, constituting, for example, the ground on which we walk; whereas another group may be a little more mobile and constitute a liquid, like water; and a third group may be so active that they constitute gas, like the air that we breathe.

We state the matter in practical terms by saying that at a given temperature one substance is solid, another liquid, and a third gaseous; and that by changing the temperature the same substance may be changed from one to the other of these states. By applying heat to the solid, we change it into a liquid, and by applying more heat we change the liquid into a gas. But the thing to recall is that what we mean by the phrase "applying heat" is that we have given an added push to the molecules so that they thrust against each other more vigorously, just as we make the billiard-balls move more actively by shooting the cue ball more vigorously against them.

Gasoline is a good substance to use in our automobile and airplane engines because it chances to be so constituted that a push may readily be given its molecules that will set them scurrying about; and gunpowder and other explosives owe their value to the fact that they are compounds that are unstable because they contain nitrogen together with other elements that will very readily unite with oxygen if a little thrust is given that disturbs the original molecular combination.

Nitroglycerin, which, as we know, was the original type of modern high explosives, is a complex compound of carbon, hydrogen, nitrogen, and oxygen. Lyddite and tri-nitro-toluol are of similar composition. When a disruptive force is ap-

plied to these complex molecules, the nitrogen is set free, and the liberated oxygen atoms combine on one hand with the carbon to form carbonic gas, and on the other with hydrogen to form water, which at the high temperature involved has the form of a truly gaseous vapor. Every atom of nitroglycerin is available for the purposes of an explosive; whereas with old black powder more than half the bulk remains in the form of solid compounds of potassium and sulfur—hence the smoke. (T. N. T. also liberates a visible residue.)

But if you ask *why*, at a given temperature, the potassium salts remain solid, whereas nitrogen and the compounds of carbon and oxygen are gaseous, no chemist in the world can give you the answer. No one knows *why* the gasoline in your automobile cylinder takes on the activities which characterize the gaseous state at a certain temperature, whereas kerosene, for example, becomes equally active only at a higher temperature, and water at a still higher. So I suppose that if a carping critic wishes to say that the man of science does not know—in the full sense of the word—just *why* the automobile moves without any horses hitched to it or *why* the bomb explodes, we must admit that he is right. Here as so often elsewhere we must be content to know the *hows* rather than the *whys* of things. However far we push back the bounds of knowledge, we come ultimately to the realm of mystery.

DYE STUFFS AND EXPLOSIVES

It remains to say a few words about the practicabilities of manufacture of explosives, tho our chief concern is with principles only.

Not long ago I visited an establishment in lower New York where beautiful textures are woven for ornamental draperies and furnishings. I saw men sitting at old-fashioned looms, weaving elaborate textures of many colors and complicated patterns by a method that has scarcely been modified since prehistoric times. Even in our vaunted age of machinery, there are many fields of industry in which hand work is still the finest work.

But what perhaps interested me most in my tour of inspection was the remark of the foreman as he came into a little room, the walls of which were flanked with endless arrays of pasteboard boxes, each containing an assortment of spools of silk.

"In this little room," said the foreman, "there are samples of twenty-five thousand different colors." He hesitated, smiled a little, and added: "And when our customers come to choose the colors for their prospective furnishings, they usually demand something different from anything we have in stock."

Twenty-five thousand colors! And that only a fraction of the number possibly available. And all of these, I reflected, have been developed by chemical manipulation from one disagreeable substance—coal tar, the sticky residue left after the distillation of gas from coal. Thousands on thousands of these colors are definite chemical combinations, not mere mixtures of shades such as artists make when seeking various colors. And all are developed from the one original crude substance, by a process of differentiation, which begins with the isolation of ten so-called crude substances (including benzene, toluene, phenol,

and naphthalene), and goes on through endless manipulations, in this direction or that, according to the ultimate product desired.

The practical manipulations required are sometimes of the most astonishingly delicate character. This may be illustrated by an anecdote told by a manufacturer before the Senate Committee, to the effect that, after struggling for a year with a difficult dye, and getting only ten per cent. yields, his yields were in a single day brought from ten to ninety per cent. by one change of method; and that change consisted of—what do you suppose? It consisted in the decrease of speed of the paddles that stirred materials in the vat, at one stage of the process, by five revolutions a minute.

At sixty-five revolutions a minute, the yield was ten per cent.; at sixty revolutions a minute, the yield was ninety per cent. That kind of knowledge, as has been remarked, is not in the books and can not get into the books.

Chief interest in the matter, from the standpoint of the general public, is that by slightly modifying the processes of manufacture at various stages, it is possible to produce, not a dye, but a high explosive or a destructive gas. The process of producing the sulfur black, with which most of our stockings are dyed, is the same, up to the last step, with the manufacture of picric acid, the basis of lyddite, one of the two great shell fillers used in the war.

In the same way, the famous T. N. T. may be produced by modifying a late stage of manufacture of a large number of different dyes.

It is possible, therefore, to change the dye works into an explosive factory almost over night. And

that fact furnishes the great essential argument for the nurture and development of an American dye industry.

It has been declared that the recent war ended as fifty-five per cent. a chemical war. Few competent judges question that the next great war will be pretty nearly one hundred per cent. chemical war, so far as directly destructive agencies are concerned. Cannons throwing old-fashioned explosives are as obsolescent as dreadnaughts. At best, they kill or disable too small a number of people. Their influence is exhausted within a narrow radius. The ideal destroyer is a gas that will expand or percolate into the air indefinitely, with potentialities of reaching thousands instead of hundreds.

THE DEADLIEST WEAPON EVER DEVISED

Every one knows how such gases were used in the recent war. But that was only the beginning. The technique was relatively crude. The gases for future wars will be as superior to those used in the past war as modern explosives are superior to gunpowder.

An intimation of this is to be found in the account given in 1921 by a chemist of the Bureau of Mines before the Franklin Institute of Philadelphia, of a new chemical, said to have been developed by a British scientist after three years of research work, that is considered to be the most deadly weapon ever devised by science. It is in the form of a vapor, and extreme dead-lines is enhanced, so it is alleged, by the fact that it will penetrate any gas mask.

It was probably this or a similar chemical that

was described by the Chief of the Chemical Research and Development Division of the Chemical Warfare Service before a Congressional Committee as a liquid approximately three drops of which, when applied to any part of the skin, will cause a man's death. He added that a much smaller amount than this, or even vapor, may cause very severe slow-healing burns.

Elaborating the subject, he pointed out that if airplanes were equipped to carry a tank of this liquid gas for discharge from nozzles similar to the ordinary street sprinkler, so that it would fall like rain, everything in the path of the plane would be killed. He stated that one plane carrying two tons of the liquid could cover an area one hundred feet wide by seven miles long in a single trip, depositing enough material to kill every man in that area. He stated further that the liquid can be easily made wherever there is available electrical power, as nearly every nation has practically an unlimited supply of the necessary raw materials. It would be entirely possible for this country to manufacture several thousand tons per day, provided the necessary plants had been built. He expressed the opinion that if Germany had had four thousand tons of this material and three hundred or four hundred airplanes equipped for its distribution, the entire first American army of a million and a quarter men during the Argonne offensive might have been annihilated in ten or twelve hours.

Fortunately this deadly liquid was not then available. But it will be available in the next war, and the fact of the possible use of such a weapon to destroy the population of cities can not be too

widely known; for the probability of obviating future wars hinges largely on the development of popular sentiment. And if past experience goes for anything, about the only type of sentiment that will probably be effective will be that which concerns the fear of injury to the generality of non-combatants.

DISARMAMENT AND WAR

Let us resort once more to the paradoxical fact that Alfred Nobel, the inventor of dynamite and cordite, believed that he had taken a long step toward making war impossible, because his invention had made warfare more destructive. Ericson, the inventor of the Monitor, entertained a similar idea as to the only feasible way of ending warfare. Recent events have not appeared to sustain this view; but it is more than probable that future history will give it sanction. It seems almost a truism to say that if warfare can be made deadly enough, mankind must revolt against it, just as sane humanity revolts against the idea of suicide.

In the view of the present writer, the scrapping of all warships except submarines and airplane carriers, and of all cannon, would not be, except in name, a step toward disarmament. The submarine, the airplane, and explosive and gas-forming chemicals are the only things that to-day constitute effective armament. If any nation can gain supremacy in these, it has the world at its mercy. A Germany without a single battleship, submarine, or cannon, but with fully developed dye works and air service markedly superior to that of any other nation, would occupy a position of supremacy not otherwise to be dreamed of.

Granted an air service bringing, let us say, San Francisco, Tokio, and Melbourne—to say nothing of Chicago, Washington, New York, and Boston—within effective radius of Berlin, the question of relative population is of small concern; and standing armies have about the value of fence posts. There will be no trenches in the next war; and the firing line, if there is such a thing, will be about the safest place of refuge. Actual danger will focus anywhere from five hundred to ten thousand miles behind the firing line.

Following up Nobel's idea, one is led to question whether nations would go to war if they knew that the total population of their great cities would be instantly jeopardized, and that thousands of women and children must perish. The answer is, I think, that at the present stage of racial evolution, even this menace would not deter a nation smarting under a sense of affront from declaring war. Most of us are so constituted that we do not turn the other cheek when someone slaps us in the face. But let it not be forgotten that, under existing social conditions, most of us go through life without ever being slapped in the face. Such minor affronts as we do suffer, are susceptible of adjudication without resort to fisticuffs. With all the jostling of the multitudes, even in our crowded cities, how seldom does one see a blow struck.

That the pugnacious animal, man, should have attained such a degree of habitual self-restraint, augurs well for the ultimate amity of nations. Doubtless there must be a few more big wars that are not relatively bloodless like the last one. Doubtless a great many cities must be blotted out

—perhaps the major part of a few nations. But even that will be, from an evolutionary standpoint, a wholesome experience; because it will in effect give opportunity for application of the principle of natural selection. The nations that tend to find less suicidal means of settling their difficulties, will be the ones that advance in population, and set the example in the arts of peace.

All of which suggests the interesting paradox that actual disarmament would be a retrograde step in civilization. A consoling view, when we reflect that nothing that bears the slightest resemblance to actual disarmament has been suggested or contemplated by any powerful nation of our day.

MILITARY OLD CLOTHES

When disarmament is under discussion it is well to remember always that there is opportunity for wide difference of opinion as to what the word means or how it should be interpreted in a given epoch. A nation may agree to give up a certain equipment because its men in authority regard that equipment as obsolete.

There are those, for example, who believe that the battleship, for purposes of future warfare, has about the value of a birch-bark canoe; holding that the airship and the submarine have made the gigantic and armored ship obsolete. If one holds that belief, it is no hardship not to go on building battleships which cost forty-five million dollars each, inasmuch as for that amount of money something like one thousand bombardment airplanes can be constructed, each one of which can carry a bomb adequate to sink a battleship. An-

other and more conservative military authority—of the type, for example, that refused even to examine the Wright airplane for five years after it had demonstrated its flying capacity—may hold that the old battleship still has its uses, and so decline to disarm as regards this particular mechanism.

It requires small knowledge of history to enable one to forecast as to which nations will have a windward eye on methods of the future and which on methods of the past. The type of selective judgment that gave an equipment to frontier soldiers inferior to that of the Indians; an equipment to American soldiers in Cuba inferior to that of the Spaniards; and that could not appreciate the value of the Maxim machine gun and the Wright airplane until European nations had seized these innovations—that type of judgment can not be expected to appreciate the relative importance of aerial and of chemical warfare until demonstrations have been made in another war.

Nevertheless, there is hopeful augury in the fact that our battleships are being scrapped, and airplane carriers built in their stead. The practical demonstration that led to this rather startling exercise of official prevision will claim attention in a later chapter.

CHAPTER IV

HOW THE GAS ENGINE HELPED

IN the month of February, 1912, there tied up at a London dock a vessel of about 5,000 tons burthen, which to any casual observer would have seemed a rather ordinary looking steamship were it not for one striking peculiarity,—namely, the absence of smokestacks. The vessel flew the Danish flag and bore the name *Selandia.*

The absence of smokestacks marked the vessel as something out of the ordinary. That the craft was indeed very much out of the ordinary was evidenced in a visit paid her by a notable company of British officials, including the First Lord of the Admiralty.

The extraordinary interest thus manifested in the Danish ship is explained by the fact that the vessel was far and away the largest craft theretofore completed—in fact the only large ship then in commission—the propulsive power of which is neither wind nor steam. Ships without sails are common enough; but a steamless steamship was something new under the sun. The *Selandia,* however, was such a ship. Unlike every other large vessel not equipped with sails, she had neither coal nor furnace nor steam boilers in her hold. She was the pioneer example of a new type of ship; and if present indications are to be trusted, her construction marked a new era in maritime annals. It is within the possibilities that craft of this new type are to supersede the steam-

propelled ship in the future much as the steamship has superseded the sailing vessel.

A STEAMLESS STEAMSHIP

The explanation of the mystery is this: The *Selandia* was provided with engines of a new type, the motive power for which is supplied by sprays of oil instead of by steam. The oil spray is not burned in a furnace, but is injected into the cylinder of the engine itself, and, igniting there, expands explosively and drives the piston forward exactly as steam drives it in an engine of the familiar type. The exhaust consists of a practically colorless vapor which escapes through a tube in one of the masts that carry the wireless equipment of the ship. The exhaust from all the engines working at full speed is said to produce less visible vapor than often emerges from the motor of an automobile.

If we contrast this with the volleys of smoke that belch from the funnels of an ordinary steamship, we have a rough measure of the efficiency of the new engine, which consumes and utilizes its fuel instead of sending it up the chimney.

The oil engine which thus threatens the supremacy of the steam engine was the invention of Dr. Rudolf Diesel of Munich. The inventor had the usual amount of difficulty in bringing his invention to the attention of the commercial world. But the success he achieved (1912) justified, in a measure at least, the glowing predictions in which he indulged in a lecture before the Institute of Mechanical Engineers in London.

The lecture was given at a time when the coal strike was at its height; when two and a half

million men were out of work in consequence; when British railways were running on half schedule; when many ships were tied up at their docks for want of coal; and when the entire industrial activity of England was temporarily in check.

Dr. Diesel declared that his invention would make a repetition of this disaster impossible. His engine would permanently break the monopoly of coal. He had solved the problem of using liquid fuel for power production in its simplest and most general form. Any of the natural liquid fuels could be used,—and what was more, used simply and economically.

He declared that there is probably as much liquid fuel as coal on the globe. New petroleum sources are constantly being discovered. The world's production of crude oil increases and may be expected to increase. Even at present, forty per cent. of the production of mineral oil, it was declared, would supply the whole naval and mercantile fleet of the world with ample power were they equipped with Diesel engines.

Of course inventors are proverbially sanguine; but in the present case the predictions of Dr. Diesel have back of them a record of accomplishment that insures them very serious consideration. The Diesel engine has passed through a period of probation during which it has been used successfully in small engines of many types. The *Selandia* was the first large vessel equipped with an oil motor to be put in commission, but numerous other vessels, some of them even larger, have been built. The interest of the British Admiralty has already been referred to. It was said that

the German Admiralty was building a cruiser to be equipped with two six-cylinder engines each of 6,000 horse-power. A sister ship to the *Selandia* was put in commission a few months later, and the East Asiatic Company is reported to have given orders for two similar vessels, and for two cargo vessels, all to be equipped with Diesel engines.

The explanation of the popularity of the new engine is not far to seek. It is founded on efficiency and cheapness of operation. Tests have been made on large Diesel engines, showing the consumption of only 0.38 pounds of fuel per brake horse-power-hour. Marine engines actually in use average 0.4 to 0.44 pounds of fuel per brake horse-power-hour, running under full load.

Contrast these figures with the 1.46 pounds of coal required to produce the same result, and it will be clear that the champions of the new engine are not mere visionaries.

It is estimated that the Diesel engine would drive a ship as fast and as far with 100 tons of fuel as the best steam engine would with 350 tons of coal. As the liquid fuel may be stored in tanks placed in the double bottom of the ship, there is an obvious saving in space that is of great importance. The space formerly occupied by boilers and coal bunkers will be available for passengers and cargo.

The Diesel engines themselves in the *Selandia* occupy about as much space as the engine equipment alone of the ordinary steam plant; but even in this regard a further economy of space will be possible. Meantime the engine room of the new craft is not only guiltless of dust and smoke,

but is cool and comfortable. The glare of flame-belching furnaces of the ordinary steamship, along with the torrid heat and the picturesque array of stokers sweltering and begrimed—are strikingly conspicuous by their absence.

How far the Diesel engine has passed beyond the experimental stage will be further evidenced when it is noted that the *Selandia,* a vessel of 370 feet length and 58 feet beam, was not merely a cargo boat, but had accommodation for about a score of passengers who were comfortably quartered in a deckhouse forward of the engines in large cabins having bathrooms en suite. The engines of the *Selandia* were in two sets, each having eight cylinders of 20.8 inches by 28.7 inches giving together 2,500 indicated horse-power at 140 revolutions per minute. The general appearance of the engine is that of ordinary reciprocating steam engines.

The operation of the engine may be briefly described thus: The upward stroke of the piston sucks air into the cylinder. The return stroke compresses the air to about 300 atmospheres, and hence heats it to a high degree of temperature. A spray of oil is then injected into the compressed and superheated air. The heat of the compressed air ignites the oil spray spontaneously, so that its combustion is effected without the use of any igniter such as is used with gasoline engines. This obviously simplifies the action of the engine; and the method of operation permits the use of any crude oil.

It will be obvious that the Diesel engine is a modification of other types of oil engines, and not in itself an absolutely new creation. It will

be clear, also, that its operation is the four-cycle stroke familiar as the Otto cycle. Like the gasoline engine, it can be so constructed as to operate on a two-cycle principle.

In these respects the Diesel engine affords no novelties. Its unique feature is the utilization of compressed air, which does away with special apparatus for igniting the oil. The fact that crude oil of any type may be employed gives it vast commercial importance.

AN ALL-IMPORTANT MECHANISM

The internal combustion engine, of which the Diesel engine is the newest type, was in some respects the most important mechanism developed in the closing decades of the nineteenth century. Three revolutonary craft—the submarine, the dirigible balloon, and the airplane—owe their existence to this engine. With its aid the depths of the sea and the heights of the air are being made accessible.

When we reflect, further, that the conditions of land traffic are being revolutionized, thanks to the automobile, through the same agency, and that the motor-boat is becoming an institution of importance,—even should the Diesel engine fail to drive the steamship off the sea,—it will be apparent that no review of recent progress would have even a semblance of completeness that did not pay full tribute to the gas or oil engine.

The definitive improvements that gave the gas engine commercial value were made by a German, Dr. N. A. Otto, as long ago as 1876, but the development of a compact, high-speed type of oil

engine, largely through the efforts of Herr G. Daimler, is much more recent.

As finally perfected, the internal combustion motor is responsible in our generation for an industrial revolution comparable only to that effected at the beginning of the nineteenth century by its prototype the steam engine.

We have just been introduced to the newest type of oil engine, the Diesel motor. Our further concern is not so much with the gas engine itself as with the space-conquering mechanisms that it has brought into being. The most obvious and universal of these, and the one that up to the present is the most significant as an economic factor, is the automobile. It is also the one that played perhaps the most important part in the war, tho little heralded except as regards a modified form, in "caterpillar" tractors, dubbed the "tank."

It would be quite superfluous to describe the mechanism or the method of operation of this vehicle, but a few statistics as to its recent development may not be out of place.

AUTOMOBILE AND SUBMARINE

It was estimated that there were 677,999 automobiles in use in the United States in the summer of 1912. It was further estimated that more than 200,000 of these machines were manufactured here in the year 1911, and above a third of a million in 1912. Ten years later (1922), there were 10,506,660 automobiles in use and the annual production has risen to about two million, including about two hundred thousand motor trucks.

These figures are impressive. They become

doubly so when we reflect that this colossal industry has been developed in the past twenty-five years. In 1899, the wholesale value of motor cars produced was $4,750,000; in 1922, it was well above a billion dollars.

In the face of this sudden development of popularity of the self-propelled vehicle, it is interesting to recall that the prototype of the automobile was invented more than a century ago, and that steam-propelled omnibuses were used commercially in England as early as 1830. Public prejudice, instigated perhaps by the owners of horses, led to the enactment of laws that virtually ruled the automobile off the roads of England before the middle of the nineteenth century, and the vehicle did not gain a footing elsewhere until the invention of rubber tires and the perfection of the gasoline engine had made possible the type of motor car that is making such universal appeal in our own day.

The case of the submarine boat is historically not dissimilar. Invented in Revolutionary days, it met with so cold a reception that almost a century elapsed before it made another conspicuous bid for favor. Then, however, toward the close of the nineteenth century, its cause was espoused with fervor, in particular by the American inventor, Mr. John P. Holland, whose efforts were largely responsible for the development of the submerged craft as a practical war-machine. Another American, Mr. Simon Lake, perfected submarine craft adapted not only for warlike uses, but also for the peaceful exploration of shallow water, salvage operations, and the like. Mr. Lake's submersibles are of "even-keel" type.

As recently as the time of the Spanish-American War, the authorities still looked askance at the anomalous vessel. But by the year 1914 submarines were as much a part of the equipment of a modern navy as were battleships. Submarines had been lowered to a depth of more than two hundred feet, where the pressure sustained was fifteen thousand tons. They had been navigated for forty consecutive hours without coming to the surface. Equipped with torpedoes they were admitted to be instruments of naval war that not even the dreadnaught could ignore. The newest types were equipped with small cannon to operate at the surface, tho their rôle in this position was conceded to be subordinate.

Then came the actual test in warfare. What the submarine then accomplished is matter of history that will claim our attention in another place.

THE DIRIGIBLE BALLOON

In marine warfare, the natural opponents of the submarine boat are the dirigible balloon and the airplane, for these craft, from their coign of vantage, can detect the location of the submarine at its greatest depth.

As regards these aircraft, a marvelous change has come about in the brief period since M. Santos Dumont astonished the world by driving a small balloon round the Eiffel Tower, on the 19th of October, 1901. This was the feat that first convinced the skeptics of the feasibility of directing the flight of a balloon. A less convincing exhibition had been made a few months earlier at Lake Constance by the German military

officer, Count von Zeppelin. But the voyage of Santos Dumont began and ended at the same place; whereas Count Zeppelin's balloon came to grief a little over three miles from its starting point.

The circuit of the Eiffel Tower demonstrated the possibility of directing the course of a balloon either across the wind or against it. But most people were skeptical as to any practical developments of so exceedingly clumsy an affair as a balloon; and only the more visionary would have predicted that in the course of a decade there would be scores of dirigible balloons in the air, some of them offering passenger service, and that every up-to-date nation would have its flotilla of airships of war.

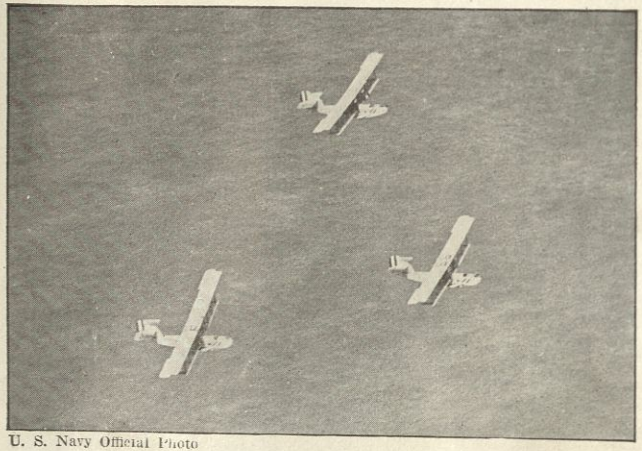
The development of the dirigible balloon in succeeding years was very largely due to Count von Zeppelin, whose energies led to the construction of one airship after another, and who was utterly undeterred by the repeated catastrophes that overtook his successive crafts. The flight of the Zeppelin III from Friedrichhafen on Lake Constance to Berlin and return in August and September, 1909, afforded a demonstration of the possibilities of aerial navigation that could not be ignored. The ship was destroyed a little later, to be sure; so were sundry of its successors, including the Deutschland I and Deutschland II. But disaster came while the ships were at anchor or near the earth; when in full flight the "Zeppelins" proved themselves craft of great stability and dependableness.

Equal praise must be given the balloons of a different type which were developed by another

German, Major von Parseval, and which bear his name. One of these made regular trips out of Berlin in the pre-war days and had a record of 4,000 miles without a single accident to its motors.

The Zeppelin and Parseval balloons may be considered the type specimens of the two chief types of dirigibles. The essential difference is that the Zeppelin type of balloon has a rigid or semi-rigid framework of aluminum over which the air-tight casing of the balloon proper is stretched; whereas the Parseval type is without such a framework. In each case the balloon proper is composed of a series of disconnected gas-bag compartments. Both types of balloons are driven by propellers not unlike those of a steamship (those of the Parseval, however, having canvas vanes), and depend for their dirigibility upon horizontal and vertical rudders, the former of which are not unlike the wings of an airplane.

The Parseval airship is supplied with an ingenious internal mechanism, which serves the double purpose of aiding in steering the ship and of compensating the loss of gas, which is always a serious item in a long voyage. This apparatus consists of two airbags or ballonets, within the main body of the balloon, capable of being independently filled with air or exhausted. If the forward ballonet is filled with air and the rear one deflated, the prow of the balloon is thereby made heavier and tends to head downward; and of course the conditions are reversed if the front ballonet is deflated and the rear one filled with air. If so much hydrogen is lost from the balloon



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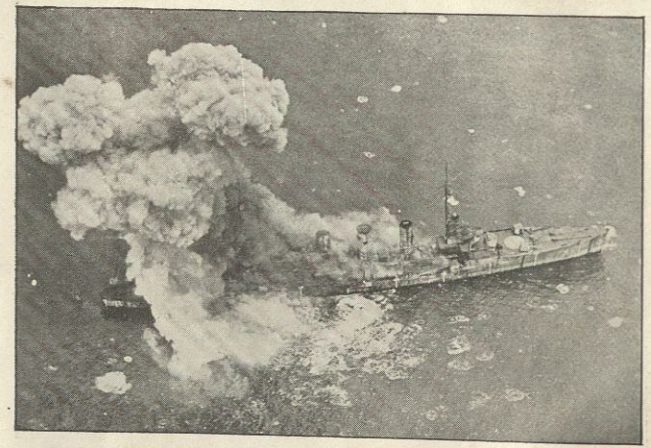
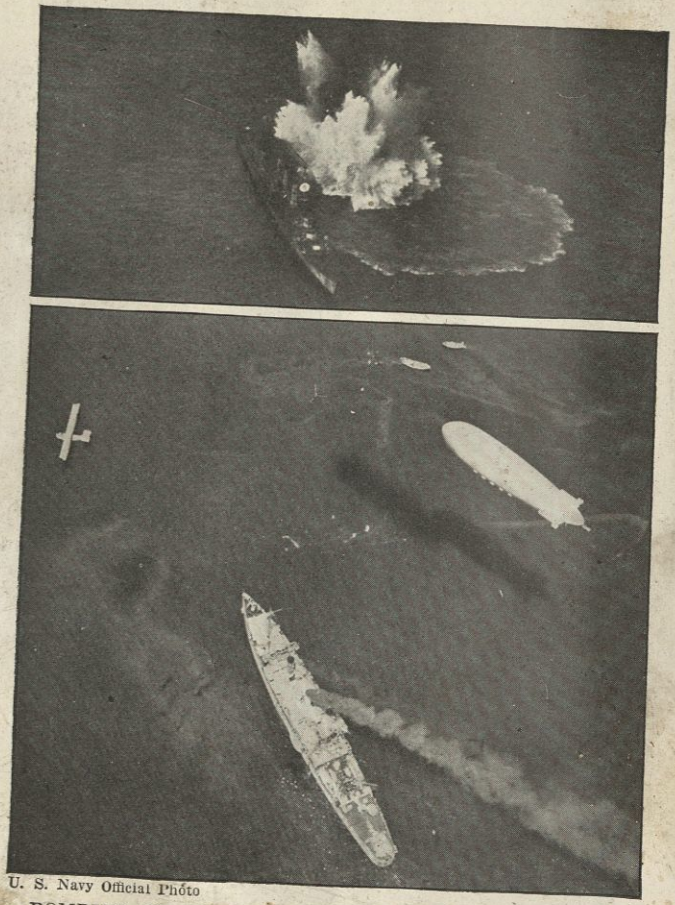


NAVY F 5 L BOMBERS, AND THE BOMBING OF THE *FRANKFURT*



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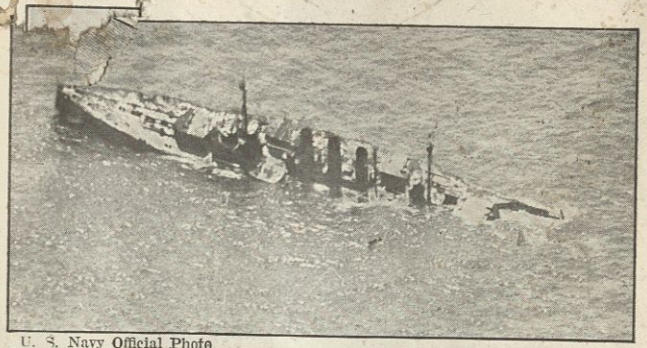
BOMBING OF THE *FRANKFURT*. NOTE SHADOW AND REFLECTION OF THE BLIMP THAT IS STANDING BY FOR OBSERVATION



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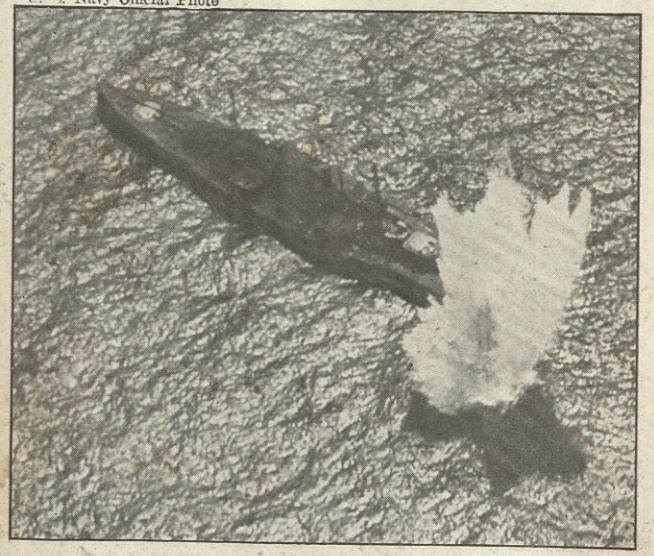
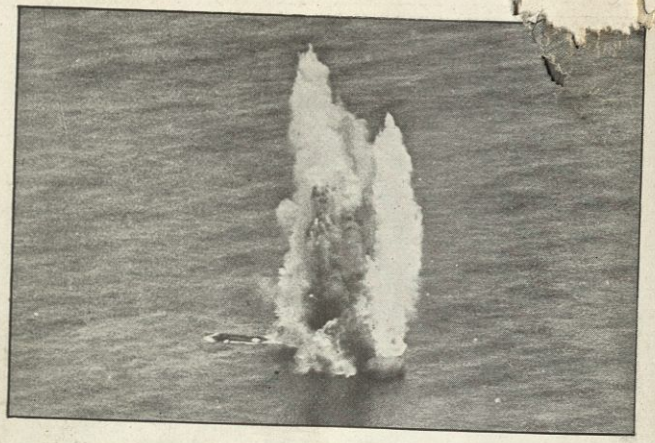
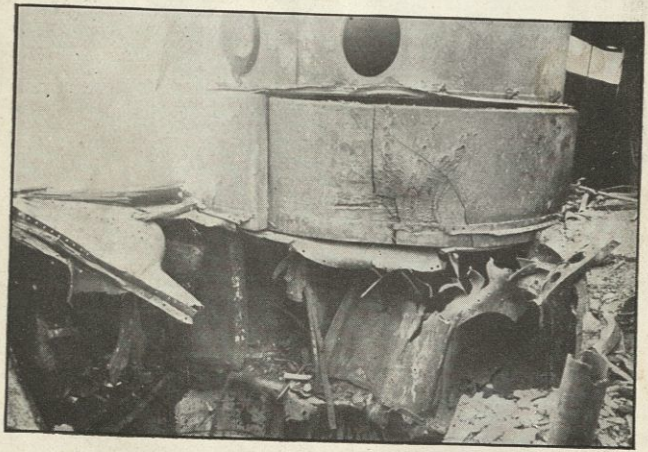
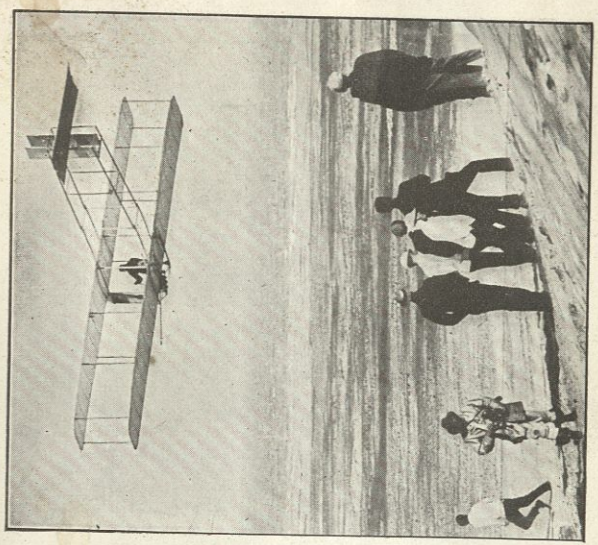


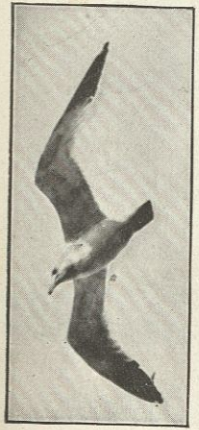
THE DREADNAUGHT *OSTFRIESLAND* SUNK BY BOMBING PLANES IN TWENTY-ONE MINUTES

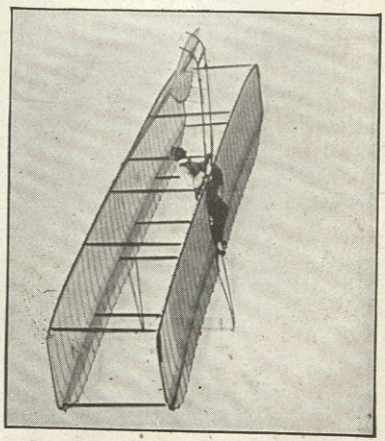




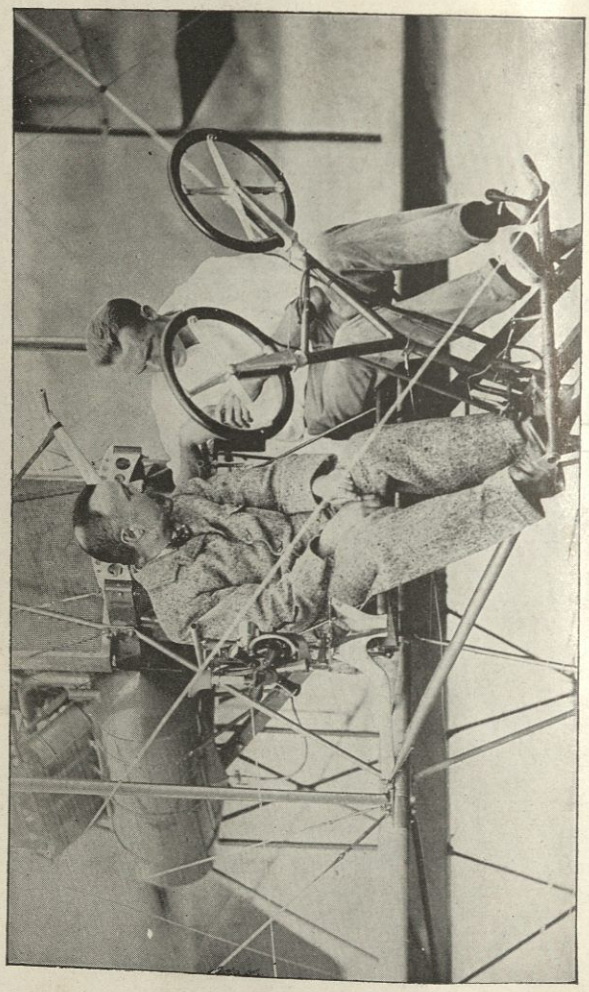
BOMB-SMASHED TURRETS OF THE *INDIANA*,
AND A "SECOND SALVO"



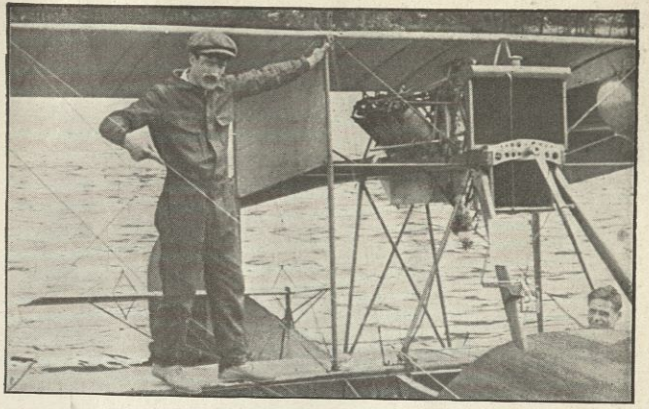


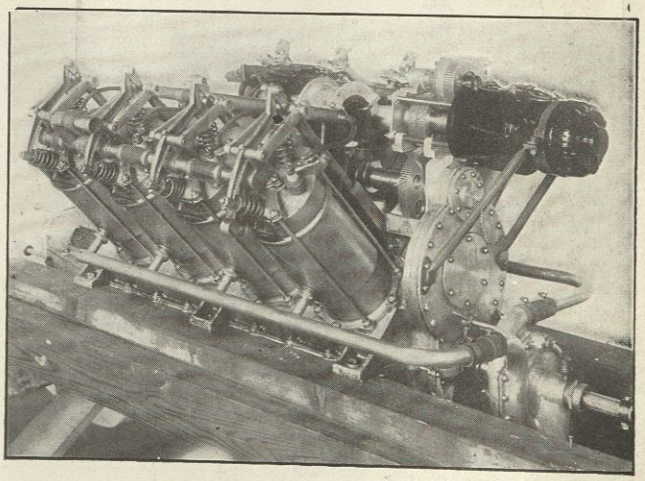


EARLY GLIDING EXPERIMENTS OF THE WRIGHT BROTHERS AT KITTYHAWK,
AND A SOARING GULL



FLYING "HANDS OFF" WITH GYRO STABILIZER AND NEW SPERRY DEVICE FOR ASCERTAINING DRIFT





AVIATOR LAWRENCE SPERRY IN HIS GYRO HYDROAIR-PLANE, AND (BELOW) THE GENERATOR-DRIVE AND CONSTANT-SPEED TRANSMISSION APPARATUS ATTACHED TO CURTISS O X MOTOR

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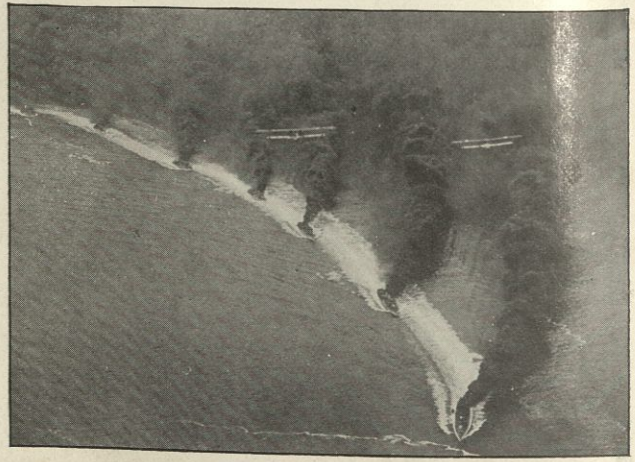


DESTROYERS THROWING OUT A SMOKE SCREEN, AND GAS-MASK DRILL ON BOARD THE *PENNSYLVANIA*

that there is danger of collapse, both ballonets may be inflated and the loss thus compensated.

When it is recalled that air is about fifteen times heavier than hydrogen, it will be obvious that the air pumped into the ballonets serves as ballast. The use of air for this purpose seems to mark an important step in the art of aeronautics. The recognized form of ballast in the early days of ballooning was the sand bag. This serves a useful purpose in lightening the balloon, but the sand once thrown out obviously can not be replaced. What is needed is a form of ballast that can be taken on or thrown out at will. In the day time the sun heats the gas bag and the balloon expands and tends to rise. At night the gas cools and the balloon settles. It was to compensate this erratic tendency of the balloon that Mr. Wellman in 1912 invented his much-talked-of equilibrator, consisting of gasoline tanks and blocks of wood arranged to trail in the water, and thus to add weight to the balloon when it tended to rise. The equilibrator proved a dangerous accessory, however, when it encountered heavy seas.

Mr. Vaniman, the chief engineer of Mr. Wellman's ill-fated trip, planned a new type of equilibrator which should dip up water when weight was needed and empty it when not needed. But such contrivances are clumsy at best, and the solution of the ballast problem must be looked for in quite another direction.

The air-chambers devised by Major Parseval (and which were adopted as accessories in both the Wellman and the Vaniman airships) afford at least a partial solution of the problem. Mr.

Brücker planned to cool his airship in the daytime by spraying it. Other attempts to maintain the hydrogen at even temperature have utilized the plan of having a double-coated balloon with an air-chamber surrounding the gas-bag. Just before his death Vaniman attempted to solve the problem from the other point of view, by making the balloon-envelop strong enough to withstand the pressure of hydrogen expanding under influence of the sun's rays. Apparently any material stout enough to resist this pressure would prove much too unwieldy and heavy. But Vaniman's balloon exploded in its trial trip off the Jersey coast in 1912, the inventor himself and his companions falling to their death.

It is possible that the final solution of the gas-expansion problem may be found in a system of refrigeration pipes, similar to those used in cold-storage plants, or conversely in a system of ordinary hot-air pipes operated from the engine-room. The use of non-explosive helium gas in place of hydrogen will make operations feasible that could not safely be undertaken before.

The most difficult problem that has confronted the makers of airships since the elementary principles of dirigibility were solved, has had to do not with the actual flight of the ship but with the safe landing of the craft. The cigar-shaped aircraft, with its thin shell of silk and rubber, is obviously a frail structure. When not in use it must be housed in a tunnel-like shed. The sheds originally made at Lake Constance were stationary, and it was impossible to bring the airships out except when the wind blew almost directly in line of the long axis of the shed. Even a mild

lateral wind would bring such pressure to bear as probably to break the airship in two. This, indeed, is precisely what happened to the British naval airship "Mayfly" when it was being towed out of its shed for its maiden voyage.

The difficulty can be met by having the shed so constructed as to rotate on its axis, like a draw-bridge. The alternative is to have tracks extending from the mouth of the shed, on which the airship may be securely anchored and thus given complete rigidity before being run into the shed.

Of course the Germans had no monopoly in the building of airships. The French were close competitors, and their war-balloons, particularly those of the Clement-Bayard type (including the "Morning Post," which was built in France and piloted across the Channel to England) were highly efficient. But the passenger service of the German dirigibles prior to 1914 gave them particular interest. The equipment of the passenger coach of the two "Deutschlands" and their successor the "Schwaben," compared not unfavorably with that of a railway coach. The cabin had an aluminum frame lined with mahogany and rosewood and inlaid with mother-of-pearl. The cabin was about 35 feet long and 7½ feet wide, and divided into five apartments equipped with wicker chairs. The window openings were of course wide, so as to give an almost unobstructed view in all directions. There was room for 24 passengers and a crew of 8 men.

The destruction of the Deutschland on its second trip, tho unattended with loss of life, doubtless dampened the ardor of a good many

would-be passengers; but the long series of safe passages achieved by the Schwaben and the Parseval ships served to restore confidence, and there was every reason to suppose that the airships would grow in popularity.

The ships had proved themselves able to travel in all kinds of weather, and their speed compared favorably with that of the fastest ocean steamers. The Parseval ship "L. P. VI," for example, made a trip from Munich to Berlin, a distance of 346 miles, at an average speed of 26 miles an hour. The Schwaben had three 145-horse-power motors, capable of driving the ship at a speed of about 35 miles an hour. Its carrying power was 20 tons at sea level.

All this is presented by way of reminiscence and history, to call to mind the status of the dirigible balloon in the period immediately preceding the outbreak of the war. Enough had been accomplished to make it appear certain that transcontinental and even transoceanic airship passenger service would be available within a few years.

It was clearly recognized, however, that it was not the potential importance of such service that accounted chiefly for the rapid development of the airship. The real spur to inventive ingenuity, accounting for the official interest in the airship so ardently manifested in Germany, France, and England, was understood to be the possibilities of the craft not as an agent of peaceful commerce, but as an engine of war.

In a review of progress, published in 1913, the present writer expressed this view, adding: "The possibility of launching a ton or two of dynamite from the safe heights of the upper atmosphere

upon the deck of an enemy's ship or within the walls of his fortress, is the vision that inspires the European powers-that-be in their official aid to the development of the airship."

Such an opinion was then heretical; for was it not known that international agreement forbade the launching of such missiles from the air? Yet only a year or so later, Zeppelins were launching bombs not against warships and fortresses merely, but to the destruction of noncombatants in their homes in the heart of London itself.

That these raids were ultimately discontinued was not due to any change of heart on the part of the foragers, but solely to the fact that the great gas-bags proved vulnerable to the attacks of airplanes equipped with guns for firing incendiary bullets, supplemented by anti-aircraft guns directing their fire with the aid of giant searchlights from the ground.

The salient point of vulnerability of the Zeppelins was their hydrogen gas content. It required but a spark to ignite the vast volume of hydrogen, spelling utter demolition. Had helium gas been available in quantity, the entire story of depradation by dirigibles would have been far different. Just before the war closed, helium gas was being extracted in quantity from the gas of certain wells in Texas; and the fact that a terrible weapon was about to be available for the allies may have had a share in determining the originators of the method of attacking cities from the air to accept terms of capitulation.

The capacity of the Zeppelin as a long-distance voyager was demonstrated in November, 1917, when the dirigible known as L-59, specially de-

signed for the purpose, made the celebrated flight from Jamboli, Bulgaria, to German East Africa and back, without landing, in 96 hours. The non-stop flight of 4,500 miles established a record that up to the time of present writing (1923) has not been equaled.

The airship that made this memorable flight had a capacity of 2,400,000 cubic feet, a useful load of fifty-two tons, and a speed of sixty-five miles per hour, using five motors.

The second long-distance honors go to the dirigible which in 1919 crossed the ocean from England to America, anchored for a time on Long Island, and in due course made the return voyage, quite without untoward happenings.

More detailed consideration of the war-time activities of the airship is reserved for a later chapter.

THE TRUE FLYING MACHINE

Even the most powerful dirigible is, after all, a floating apparatus rather than a true flying machine. It owes its buoyancy to the fact that it displaces more than its own weight of air. Therefore it rises on the same principle that causes the rise of the child's toy balloon. In directing its course upward or downward, as well as laterally, the influence of guiding planes or rudders is of course necessary, and the propeller blades, driven by powerful gasolene engines, grip the air precisely as the propellers of a steamship grip the water; so of course their propulsive power, combined with the adjustment of the guiding planes, gives the balloon a degree of stability in the air and of buoyancy that it would not otherwise have.

Indeed, in the case of the first successful dirigible of Santos Dumont, the buoyancy was almost entirely due to the propellers and horizontal rudders, the balloon with its passenger being only slightly less heavy than the air it displaced.

But it is obvious that a flying machine that must be lighter than air is necessarily of such bulk as to be unwieldy; and all along the ideal that inventors had set themselves was the perfection of a machine that would not be dependent on bulk for its buoyancy; one that could imitate the birds and bats in performing veritable flight in the air rather than merely floating, however accurately directed. In other words, the mechanism sought was a heavier-than-air machine that would fly.

In that first year of our new century, however, in which Santos Dumont achieved success with his marvelous dirigible, there were not many men of accredited scientific standing in the world who thought that this ideal would ever be attained. Indeed, there was only one famous scientist who was making conspicuous efforts toward the practical realization of the ideal. This was Professor Samuel H. Langley of the Smithsonian Institution.

Sir Hiram Maxim had, indeed, performed some remarkable experiments a few years earlier, constructing a gigantic air machine, which, driven by propellers, lifted itself in the air and made a short flight stabilized by guiding rods. But Langley attacked the problem from a different angle, and produced a model flying machine, with two pairs of canvas wings set tandem and having a spread of eleven feet, which, driven by a light

motor of special construction, made a wonderful flight above the Potomac and settled to the water uninjured.

But Langley's larger flying machine, constructed on the model of his "aerodrome," plunged into the Potomac River in the attempt at launching, December 8, 1903. The inventor was heartbroken; and the entire public chorused, "I told you so," and gave the matter no further thought.

The entire public? Not quite; for among the seventy-odd million of the American people there was an undistinguished minority of two individuals who differed from their fellows as to the feasibility of human flight. These two were Wilbur and Orville Wright, obscure bicycle dealers of the little town of Dayton, Ohio. While Maxim and Langley, each in his way, had been making strictly scientific experiments, these young men, aided neither by private fortune nor public subsidy, had been devoting their spare time to experiments in gliding, following up the work of the ill-fated Lilienthal and of Messrs. Herring and Avery and Chanute.

They had invented a new type of bi-plane glider, and had learned to manipulate it with unexampled skill.

Finally they attached a gas engine and some wooden propellers to the glider, and on the 17th of December, 1903, little over a week after the final mishap to Langley's machine, they put their strange new craft to the test. In the presence of accredited witnesses, with one of the inventors abroad, the weird contrivance lifted itself into the air, made a flight of 852 feet in the face of a

twenty-mile wind, and landed its passenger in safety.

That day the airplane was born. The body of this wonderful mechanism consisted of two horizontal planes of canvas stretched over light wooden frames, with their long diameters adjusted transversely to the direction of flight, like the wings of a bird. The box kite had supplied the obvious model for the body of the airplane; and a gasoline motor driving two pairs of wooden propeller blades served to push the apparatus forward and virtually supplied a buoying air current comparable to that supplied the box kite by the wind.

A kite can not fly unless the wind has a certain strength; nor could the Wright airplane sustain itself in the air unless driven forward at a relatively high speed—not far from forty miles an hour. As originally operated, it received initial momentum from a catapult-like arrangement, and needed also the aid of the wind to help support it until it acquired full momentum.

Once in the air, however, it attained a speed of forty or fifty miles an hour, and its course could be steered in any direction regardless of the air currents.

A pair of horizontal rudders, originally placed in front of the main wings but in later models at the rear, provided for the vertical guidance of the apparatus; and a pair of vertical rudders at the back steered the machine to right or left.

An equally vital feature of the steering mechanism was the fact that the main wings of the airplane were so constructed that their rear edges could be warped independently; thus varying the angle of incidence and hence the resistance to air

pressure. By warping the edges of the right wings downward, those of the left wings remaining stationary, the machine would be made to tip to the left; the reverse warping would produce the opposite effect. A method was thus provided for meeting the disturbing influence of changing air currents and gusts of wind, which otherwise would overturn the machine. The vital importance of this feature of the mechanism is obvious.

But since the warping wings of the machine, while stabilizing it laterally, would tend to deflect it from its course, the apparatus was so arranged that a single lever controlled the flexible portion of the wings and the vertical rudders, the guidance of the latter counteracting the disturbing influence that would otherwise result from the twist of the wing tips. The discovery of this combination constituted the crowning achievement of the Wright brothers, and made their airplane a manageable mechanism. In other words, it made the flying machine a machine in which a man could fly.

All this was accomplished, as we have seen, in 1903. But for a time the Wright brothers did not take the public into their confidence, being chiefly concerned in interesting our government in the airplane as an auxiliary instrument of war, and it was not until 1906 that the details as to the principles of the wonderful airplane were accessible through Patent Office specifications. Then a host of imitators set to work devising air craft of many patterns. Some of these are to casual observation very different from the Wright machine; in particular the monoplanes, of which M. Blériot's is the best known. But in their prin-

ciples of operation all airplanes yet devised are identical. No heavier-than-air machine (except the experimental helicopter) has yet carried a passenger in safety that did not depend for its stability upon warped wings or their equivalent, combined with the use of vertical and horizontal rudders.

It is worth while to emphasize this point, because attempts are constantly made to becloud the issue. It has been urged that the Wrights were not absolutely the first users of any one of the devices that they combined to make their airplane. They did not invent the canvas planes or the vertical or horizontal rudders or the warping wings or the motor. Very true; but they used them first in successful combination, producing for the first time in history a flying machine heavier than air that would fly and carry a passenger, and go where directed and land in safety. Their title as inventors of the airplane is far clearer than the titles of the accredited inventors of the steamship, the steam locomotive, or the telegraph.

So the 17th of December, 1903, must stand out as one of the memorable dates in the history of civilization. And there is every reason to believe that in the remote stretches of the future the names of Wilbur and Orville Wright will be remembered when the bulk of the names that now loom large in our generation are utterly forgotten.

HIGH FLYING

The early history of the development of the art of flying is a matter of common knowledge. But it may be of interest to recall a few specific achievements.

On the 17th day of September, 1912, a French aviator, M. Georges Legagneaux, soared into the air in his monoplane, and in the course of three-quarters of an hour had attained the dizzy height of three and a half miles; or, to be more precisely accurate, 5,720 meters, or 18,761.60 feet. The accomplishment gained wide attention, because it constituted a record; yet it can scarcely be said to have occasioned surprize, for after all it exceeded a record made ten days before by M. Garros by only about 2,500 feet. Meantime another aviator had gone to the height of 13,000 feet carrying a passenger; and yet another had piloted two passengers more than a mile and a half into the air.

Moreover, the record made by Legagneaux was surpassed by Garros, who attained 18,400 feet at Tunis, on December 11th; and this record in turn gave way to one established by M. Perreyon in France on March 11, 1913, the new record being 19,685 feet, or almost three and three-quarter miles.

It was thought that the limit had nearly been reached with motors of the present type, as the air at this great height becomes so thin as to reduce greatly the lifting power of the airplane and the horse-power of the motor. The great cold makes the feat difficult for the aviator, and it is usually necessary to inspire oxygen carried in a tank. All in all, the feat of bestriding a ton of steel and canvas and lifting the unwieldy hulk above the clouds seems little less than miraculous.

Ten years later, with the war-time experience and the "turbo-booster" to aid, records were made of yet another order, culminating with Lieut.

J. A. Macready's 34,509 feet, achieved September 28, 1921.

A high record of another type was gained (also in France) by Pierre Gougenheim in piloting an eighty horsepower biplane carrying four additional passengers to the height of 2,461 feet. The feat was accomplished in a heavy wind, and a greater altitude would have been reached but for a shower.

In September, 1913, M. Pegoud twice performed the (then) astonishing feat of voluntarily describing a letter S in the air, flying upside down for several hundred yards in so doing. Not long thereafter "looping the loop" came to be regarded as a commonplace maneuver.

The speed possibilities of the airplane were suggested by the 105.5 miles an hour made by Jules Vedrines at Chicago in 1912 over a course of 124.8 miles, in a 140 horse-power monoplane. In the matter of endurance flights and long-distance journeys through the air there were new records almost weekly. One aviator flew from the Atlantic to the Pacific; another went from Paris to St. Petersburg; and the flight from Paris to London became almost commonplace. In June, 1913, M. des Moulinais made a 933-mile flight from Paris to Warsaw, his time in the air being ten hours, and his average speed, 93 miles an hour. M. Guillaux flew 859¾ miles in a day; and, on September 15th, 1913, with a passenger, 118 miles in fifty minutes. M. Letorl flew 590 miles without a stop; and in America Mr. C. M. Wood made on August 8th, 1913, a nonstop flight from Hempstead, Long Island, to Fort Myer, a distance of 329 miles, in 4 hours and 31 minutes. (We are

reviewing pre-war conditions, of course, but for comparison it will be of interest to note the 2,200-mile flight from San Diego to Indianapolis, made November 3–4, 1922, by Lieuts. J. A. Macready and O. G. Kelly; and the same aviators' nonstop record of 35 hours, 16 minutes, 30 seconds, made October 7–8, 1922, near Coronado, California. Meantime, toward the close of 1922, airplanes controlled only by stabilizers, actuated by no human pilot, flew two hundred miles in England and ninety miles in America, respectively.)

THE HYDROAIRPLANE

But all these are matters of detail. The only really essential modifications of the airplane in the first decade of its existence relate to the methods of starting and landing. The first modification, which was introduced early by European aviators, notably Mr. Henry Farman, and which was soon universally adopted, consists of adjusting bicycle wheels to the frame of the machine. A still more striking modification depends upon an arrangement designed to permit the airplane to rise from and alight on the water. The development of this idea has resulted in the so-called hydroairplane.

The advantages of this type of air craft are obvious. They were pointed out by Octave Chanute, a pioneer in the use of soaring apparatus, in the early days of experimental aviation. Langley made his experiments over water courses, as did Hargreaves, Blériot, and Kress. But Fabre in France seems to have been the first to succeed in making a machine that would rise from the water. Mr. Glenn H. Curtiss, the American aviator, has been prominent in perfecting the appa-

ratus. It should not be overlooked that a clue was given by Wilbur Wright when he made his historic flight up the Hudson in 1909; his airplane on that occasion being equipped with a covered canoe, to give it safety in the event of an inadvertent descent into the river.

The hydroairplane is simply a combination of boat and flying-machine. But the boat must be of such shape that it will skim through the water with the least possible resistance, and equipped with a powerful motor.

At the present time two types of hydroairplanes are popular, one of which might be described as a flying-machine with floats, the other as a boat with wings. In the first of these, the floats, two in number, are in the form of a catamaran, the operator occupying a seat in the same position as on the airplane. In the other, the single hull serves as a seat for the operator as well as a float, and the craft, if shorn of its wings, would resemble the racing type of motorboat. These single hull hydroairplanes are kept from capsizing by small auxiliary floats placed beneath the tips of the wings, and it is claimed by the advocates of this type that it has manifest advantages over the catamaran in rising more readily from rough water.

PRACTICAL USES OF THE AIRPLANE

Before the war, little practical use had been found for the airplane except in military and naval operations. But in these it was proving revolutionary. Its success had lain largely in the field of scouting—one of the most important features of military maneuvers. How successful the

army scouts proved themselves is shown by the fact that in England the autumn army maneuvers of 1912 were terminated because the movements of the opposing armies could not be concealed from the airmen, and the commanders found the hitherto accepted tactics impractical. Thus, as "the eyes of the army," the airplane, equipped with wireless telegraph apparatus, proved its value even before the days of actual fighting.

The airplane made rapid progress as a fighting-machine as well. In August, 1912, Lieut. Scott, an American, won the Michelin Target Competitions in France, by dropping twelve out of fifteen bombs into a circle of 66 feet in diameter from a height of 656 feet. This performance placed the airplane in the position of a destructive agent that must be reckoned with.

Four classes of bombs were designed for these aerial fighters: (1) heavy explosive bombs, to be used against ships, dockyards, railways, bridges, and buildings; (2) small bombs or hand grenades, for troops assembled in masses; (3) incendiary projectiles, for destroying buildings or magazines; (4) metal projectiles, for attacking air-craft.

Meanwhile the armies and navies of the world were busy with designs of guns for destrying airplanes and dirigibles; and Col. Isaac N. Lewis, of the United States Army, perfected an automatic gun which could be used from the airship, or against it. This gun, which fires at the maximum rate of 750 shots a minute, weighs only twenty-five pounds, and is air-cooled. It was designed primarily for the use of cavalry and infantry, for which it is admirably adapted, but its unique features make it peculiarly useful as an

aerial weapon—after the customary official barriers to acceptance were overcome.

This gun was tested in June, 1912, and from a height of 600 feet placed forty-five shots in a space three yards by eighteen while the airplane was moving at a rate of fifty miles an hour. The bullets used were the regulation 30-caliber used by the army.

It remained to be seen what practical uses might be found for the airplane in solving transportation problems. Such a flight as that made in August, 1913, by Mr. Harry G. Hawker in his hydroplane flight around the British coast, in which he covered 1,043 miles in about as many minutes' flying time, carrying a passenger and making 494 miles in his best day's journey, suggested practical uses for the airplane, and particularly for the hydroplane, that began to be realized only after the cessation of the great conflict that was on the eve of eruption. The part played by this new weapon in the conflict itself will claim our attention in a later chapter.

CHAPTER V

ASPECTS OF LAND WARFARE

LAYING DOWN A BARRAGE

OF ALL the words that came from the war zone to enrich the language of our everyday life, few gained more ready acceptance than the word "barrage." At first the correspondents interpreted the word as meaning a "curtain of fire," but later the word came to be universally understood, bringing to mind a picture of a shower of shot and shell falling along a definite line in advance of attacking troops or on either side of an advancing column.

The feat of "laying down a barrage" became so familiar a part of offensive and defensive action at the Front as to be taken quite as a matter of course. Yet, if one stops to reflect on the matter, it becomes obvious that the laying down of an accurate barrage, let us say one hundred yards in front of an advancing line of troops, is a rather wonderful performance, recalling that the cannon that throw the missiles to form this wall of explosives are located at various distances in the rear, and must throw their shells over the heads of the troops in whose interest the barrage is established.

How is the artilleryman, away off there in the background, to know where to direct his weapon in order that its explosive projectile may drop at the particular point where it is needed and not a

hundred yards or so short of that point, where it would work havoc among his friends?

To answer that question in detail would require the scope of a treatise on ballistics, but a general and sufficiently explicit answer to the question may be found in the consideration of a few fundamental principles that may be briefly outlined.

First and foremost, there is the great principle of universal gravitation, which determines that every body flung into the air must fall toward the earth, or tend to fall toward the earth, at the rate of sixteen feet in the first second and with increasing speed in each succeeding second. To be sure, a cannon ball fired upward in the air appears to defy this principle, inasmuch as it ascends instead of falling. But the defiance is only apparent, for at whatever angle it is fired the projectile reaches an elevation sixteen feet less in the first second than it would have reached had gravitation not acted upon it. In each succeeding second its upward aspirations are progressively curtailed, until the energy that impelled it upward is entirely neutralized, and actual descent begins. Thenceforth the original propulsive energy suffices only to carry the ball forward while gravitation drags it downward, the net result being a hurtling descent in a curved path which the geometrician describes as a parabola.

From start to finish, the flight of the projectile has been determined as a compromise between the propulsion given it in a certain direction by the explosive in the cannon and the contradictory pull exerted by gravitation. The latter is a fixed and unvarying force, always to be reckoned with in the same terms; the former is a force that varies

with the particular type of cannon from which the projectile is fired, with the specific charge of explosives employed, and the size of the projectile itself.

There are, to be sure, minor complications. The atmosphere itself is a resisting medium; wind currents are a deflecting influence; and the fact that the projectile whirls as it flies tends to deflect it from its course—on the principle of the "curved ball' of the baseball pitcher. But these are minor influences at best. The main conflict is between the initial energy given by the explosive and the deflective pull of gravitation.

It follows that the artilleryman, knowing the weight of his projectile and the amount of so-called muzzle energy that the particular weapon will develop with a given charge, can calculate exactly how far this particular projectile under these conditions will be thrown when the cannon is given a definite elevation. In point of fact, these calculations are made for him by the manufacturer of the cannon, or those who originally test it, and it becomes a merely mechanical feat to direct the weapon at an upward angle in accordance with a visible scale or gage, to throw the projectile to any given distance within its range.

If, then, the order comes to send a succession of projectiles to a point one hundred yards in front of a trench known to be one thousand yards away, nothing more is required than to adjust the weapon at the eleven-hundred-yard elevation, and open fire. If the barrage is to be a "rolling" or "creeping" one, a slight change of angle with each successive shot will carry successive shells farther and farther.

All this obviously presupposes that the exact distance at which the barrage is to be laid down is known. But, of course, situations must constantly arise in which the artilleryman is required to direct his projectile to a distance not predetermined. It is desired, for example, to silence a particular cannon located far behind the enemy's front trenches; or to break up a nest of machine guns over on a distant hillside. The cannon that is to effect this has just been hauled to its present position, and the artilleryman has no foreknowledge of the distance of the object he is expected to bombard. Yet without such knowledge he would be firing altogether at random, and his shells might fall a mile or so this side or the other side of the intended target. How is this complication to be met?

The answer is to be found in the application of another very simple principle—the familiar law of geometry, that when one side and two angles of any triangle are known the other sides may readily be calculated. In effect the artilleryman becomes for the time being a surveyor. In theory, he establishes an actual base line, and sights the target from each end of this line, measuring the two angles. A simple calculation, to "solve the triangle," does the rest. In practise, a cleverly devised range-finder is used, which automatically solves the triangle, and records the distance of the object observed with an accuracy that should not vary by more than one hundred yards at a distance of two miles.

Having thus determined that the nest of machine guns he is expected to annihilate is, let us say, five thousand yards away, the gunner can

automatically elevate the muzzle of his weapon until it is at the right angle to throw the projectile five thousand yards. He appears to be aiming at the moon, but gravitation will see that the projectile comes to earth at not far from the desired distance. It remains, however, to direct the weapon laterally—that is to say, to aim it—in precisely the right direction.

To accomplish this, he must aim an auxiliary barrel adjusted in a vertical plane parallel to that of the barrel of the cannon itself. The principle is precisely the same as the aiming of an ordinary rifle, except that a telescope-sight will probably be used to aid vision. An interesting question arises as to what degree of accuracy may be expected of the marksman when attempting to hit on object at five thousand yards, or approximately three miles—a very ordinary range when cannon are in question.

An inkling of the difficulties involved will be gained if we reflect that at one thousand yards a line of men becomes a mere band of color, heads and legs being indistinguishable. At twelve hundred yards horsemen and footmen can be distinguished; but at two thousand yards the average eye sees a horse and man as only an infinitesimal dot.

TO KILL A MAN AT ONE MILE

Suppose a sharpshooter with a rifle should attempt to "snipe" a man standing perfectly still in the open one mile away. Suppose that he draws a perfect "bead," but at the moment of shooting an infinitesimal tremor—a pulse-beat, if you will—causes the barrel to waver by so small an amount

that the sight moves only one-two-hundredth of an inch from its original posiiton. That infinitesimal variation will so change the course of the bullet that the man aimed at will be perfectly safe. If the deflection of the gun-barrel amounted to one-tenth of an inch, the ball would fly so wide of the mark that no one would be injured, tho a company of fifteen men were standing side by side with the one aimed at.

If such difficulties confront the marksman shooting one mile, it is obvious that the artilleryman who is to shoot two or three or five miles must not expect to make a "direct hit" on too small a target. He has the advantage, however, that his weapon, once it is aimed, will not be disturbed by a tremor; and with the aid of a telescope-sight he is able to adjust his weapon with an astounding degree of accuracy. Two or three trial shots may be required to make sure of his range and to enable him to make proper allowance for the influence of the wind on a particular occasion; but he is pretty likely then to be able to drop an explosive shell within damaging distance of any object that he can definitely locate. A "direct hit" at ten thousand yards of a target as large as a "nest" of machine guns is well within his possibilities. The same thing applies, of course, to any large piece of ordnance.

Hence the necessity—viewing the matter from the opposite point of view—that machine guns and cannon should be shielded from view to the fullest extent possible. Out of this necessity grew the elaborate system of disguise which has made familiar another exotic word, camouflage. A machine gun or cannon that went into action undis-

guised out in the open would not be long in paying the price of its temerity. As the case stands, however, the artilleryman's difficulty is not so much in aiming his weapon as in seeing something at which to aim. Very commonly a whiff of smoke is his only guide—an unsteady and fugacious target.

SHOOTING AT THE INVISIBLE

Incidentally it is worth noting that the puff of smoke given out by an enemy cannon may serve a double purpose, not only enabling the gunner to direct his weapon laterally, but also giving a clue to the range, provided careful observation is made of the interval of time that elapses between the visible appearance of the smoke and the hearing of the sound. Sound waves, in the atmosphere, travel at the rate of about 1,080 feet per second, so a fairly accurate estimate of the distance of a cannon may thus be made with the aid of so familiar an implement as the split-second watch. Special implements have been devised to make the test more accurate; but the method has limited value under the conditions of present-day warfare because many weapons are usually operating together, and in the universal din it is impossible to localize the sound of any particular cannon.

The culminating feat in marksmanship in land warfare comes when the gunner is called upon to hit some object that he can not see at all—not necessarily because it is camouflaged, but because it lies entirely beyond his horizon. He is directed, for example, to put out of commission some great cannon that is being fired from a woodland over

yonder hills, five miles or so back of the enemy's line.

Such a suggestion calls to mind the proverbial search for the needle in the haystack; yet, under proper conditions, the gunner may go about this seemingly hopeless task with confidence, and with a fair chance of bringing it to a successful issue.

The favorable conditions in question include the possession of a map that will enable the gunner to locate approximately the distance and direction of his target; together with the cooperation of an airman in a balloon or an airplane who will watch the fall of his trial shots, and will send him wireless messages telling him by how far and in what direction he is missing the mark. Just how the airman accomplishes his part of this important program is another story. Suffice it here that when word comes to the gunner that his shot has fallen, let us say, three hundred yards short and two hundred yards to the right of his target, this information enables him at once to adjust his weapon to approximately the proper range. In so doing, by reading the gage of his gun backward, so to speak, he is given the exact distance; and, knowing this, he can readily estimate the amount of lateral deflection that will be necessary to bring his weapon directly in line of the mark. If, for example, the distance is ten miles, and the length of the cannon is twenty feet, the muzzle of the cannon will need to be deflected about two and three-quarter inches to align it with the target, this slight shift serving to correct the lateral error of two nundred yards observed at the ten-mile distance.

TO HIT A CITY AT SEVENTY MILES

At still greater distances the difficulties are magnified proportionately, as a matter of course. If the German gun that bombarded Paris from a distance of seventy miles was eighty feet in length its muzzle must not be deflected by more than three inches or its missile would fail to fall within the city walls—six miles in diameter. To hit a target the size of the city of Paris at seventy miles is equivalent to hitting an eight-inch target at twenty-five paces from the muzzle of your pistol. If you think that an easy task, try it.

It remains to call attention to the peculiar difficulties encountered by the naval gunner, who has the signal disadvantage of shooting from a moving platform. In the time of Lord Nelson this difficulty was met by bringing the ship close up to the enemy, and firing broadsides at so short a distance that to miss was well-nigh impossible. The naval guns at that time had no sights, and there was no particular need of them.

But modern naval battles are fought at long distance, and the problems of getting the range and carefully alining the gun by aiming are the same that confront the land gunner. The sight employed consists of a vertical and horizontal wire, the focus being, of course, at the point of intersection. With large guns, two marksmen operate in unison, one devoting attention exclusively to the vertical wire, endeavoring to keep the gun constantly "laid" on the mark; while his companion considers the horizontal wire only and at the proper moment fires the gun.

Just as the gunner has perfected his aim, however, the ship may roll, and the target may disappear from view. To fire under such circumstances would obviously be futile. Again and again the target may appear and disappear, as the ship oscillates. The gunner's most difficult task is to gage the rate of oscillation and discharge his weapon at the proper instant, as the tiny wire across which he sights appears to come in contact with the mark.

As a practical illustration of the difficulties that attend this operation it will be recalled that the Spanish warships coming out of Santiago harbor kept up a running fight practically without injury to their American assailants. The possibilities of skilled marksmanship, on the other hand, were illustrated in the same battle in the fact that the American gunners succeeded in due course in destroying the entire Spanish fleet. The supreme test of marksmanship thus successfully met by the American gunners on that occasion gave good augury of what might be expected of them in any subsequent conflict.

A FIVE-HUNDRED-MILE GUN?

A good deal was heard in 1921 of an apparatus which is practically used for driving bolts through steel plates; but which operates on a principle which is alleged to be applicable to guns of large size. It is said to have been computed that such weapons could be constructed capable of throwing a projectile several hundred miles.

Such computations are always to be taken with proper allowance. Thousands of small models of endless types of mechanisms have operated beautifully; and the large machines made after the same model have shown unpredicted structural defects.

Nevertheless the accomplishment of the German "Big Bertha" which threw projectiles into Paris, as just noted, from a distance of seventy miles or so, forbid one to regard the three-hundred-mile gun, or for that matter the five-hundred-mile gun, as an impossibility. When one is told, however, that such a weapon would make warfare impossible, one may smile indulgently and reflect that, even at a mere seventy miles, the entire city of Paris was not too large a target. At five hundred miles, the marksman should not be asked to hit anything much smaller than a continent.

Great interest attaches to the new "gun" chiefly because of its unrevealed source of power, and the statement that it operates without recoil. Action and reaction are equal. In any gun hitherto constructed, there is as much energy expended in the backward push of the weapon itself as in the forward propulsion of the bullet. If a way has been found to take up this recoil—through a set of springs or air cushions or what not—in such wise that the mechanism has no observable "kick," something of actual importance has been accomplished.

THE FLIGHT OF A BULLET

A British physician, Dr. F. W. Mann, soon after the war made a most elaborate series of studies of the flight of the rifle bullet, in the course of which he has apparently added many items of definite knowledge to a subject that is of interest to military men and sportsmen—and incidentally to baseball fans and golf enthusiasts.

One of Dr. Mann's experiments consisted of firing rifle balls through a series of thin paper

partitions, sometimes placed at intervals of only six inches. He could thus demonstrate the exact course taken by the bullet, and could also observe the gyrations of the missile as recorded by the telltale holes in the paper. That a bullet turns and twists in the air, and even goes "heels over head"—as a ballistic expert expresses it in a summary of Dr. Mann's work—has long been known; but the new studies answer many obscure questions as to the exact character of these ballistic acrobatics, and, what is more important, tell us why bullets exhibit individual peculiarities of flight.

It is known that the elongated bullet greatly exceeds the round bullet in accuracy. The reason is that a round bullet continues throughout its flight to rotate in a plane parallel to its original axis (gyroscopic effect), and hence not directly in line of its curved flight or trajectory. The result is a sidewise thrust of the air, precisely similar to that of a baseball given a "curve" by the pitcher, or a golf ball "sliced" by design or accident.

An elongated bullet, on the other hand, oscillates in such a way, owing to gyroscopic actions, that its axis of rotation changes moment by moment, keeping in line of the curved trajectory, and so not being deflected by the air-resistance. If the bullet is perfectly symmetrical, and of uniform texture throughout, it travels head-on with its point describing a curved path (helix) as it oscillates about the line of flight.

But it appears that bullets seldom are symmetrical after the gun is fired; in 120 cases out of 122 tested by Dr. Mann, the base of the missile

was somewhat distorted by the discharge. In other cases there are imperfections in the structure of the missile, so that the center of gravity is not exactly at the physical center. This necessarily modifies the manner and degree of oscillation of the bullet, causing it to turn and twist like a wobbly top, altho still spinning persistently, and being brought back constantly by gyroscopic action to its true course.

It virtually turns over and over as it spins, and so may strike side-on; but the entire series of gyrations is repeated with each revolution; that is to say, in a distance of from six to ten inches, according to the rifling of the gun from which the bullet was fired.

Incidentally it is found that it is not desirable to have the rotation of the bullet too rapid. A formula has been developed which reveals the rotation of maximum efficiency for a bullet of given size. The manufacturer of rifles thus does by rule what the baseball pitcher accomplished by instinct—the same principle being involved tho the design of one is to prevent the ball from "curving," whereas the effectiveness of the other depends on making it "curve."

A THOUSAND BULLETS A MINUTE

"In years to come," wrote a correspondent at the front, "American tourists will go to see Chateau-Thierry. They will not see the débris and carnage I saw yesterday, but it will be many years before the war marks are wiped away. Remember that on that line of white stone houses on the south bank of the river the American machine-gunners after a thirty hours' ride in camions from

another part of France, placed their tools of war and held for thirteen hours against the mad rushes of the oncoming Germans to get across the river."

The picture thus presented—showing a contingent of machine-gunners spraying the oncoming enemy with bullets somewhat as a gardener sprays a flower-bed with water from a hose—might be said to be a typical picture of present-day warfare, for the machine gun as a perfected instrument of warfare is a mechanism of our own time.

It is interesting to recall that this remarkable weapon, employed now in every army of the world, is of American origin. It is true that the prototype of the machine gun—the multiple-barreled weapon called the mitrailleuse—was devised by the French, but this awkward instrument, with its showers of bullets striking together, gave only a vague forecast of the machine gun of to-day. The true pioneer was the American, Dr. Gatling, whose repeating-gun, worked with a crank, was a really formidable weapon, but the genuinely "automatic" weapon was perfected by another American, Hiram Maxim, whose work, however, was not appreciated by his official countrymen until it had received the sanction of a foreign government.

What the machine gun can do on a comprehensive scale was first demonstrated by Lord Kitchener at the Battle of Omdurman, where the dervishes were mowed down to the number of ten thousand killed and fifteen thousand wounded, their army virtually annihilated before they could strike an effective blow against the small British force behind the modern weapon. That demon-

stration sufficed to make it clear that tactics of warfare must be changed for all time; and the lesson was emphasized at every stage of the recent war. A commander who would send his men in mass formation against a position held by machine guns would be counted a madman.

Of what avail are numbers against even a small group of men each armed with a weapon that can throw from five hundred to a thousand bullets per minute? The wonder is that positions thus defended can be taken at all. And the wonder grows when we reflect that nowadays every soldier is, in effect, armed with a modified machine gun—a repeating rifle, one capable of shooting fast enough to put twenty men out of commission before they could compass an intervening space of as many rods—provided each bullet found its mark.

EFFECTIVE BUT NOT EFFICIENT

That proviso, however, suggests another aspect of the story. As a rule, the bullet does not find its mark. The average man, even tho a trained soldier, is not a marksman. Whether he operates machine gun or rifle, he throws away most of the lead that he shoots. By rare exception does a bullet find a human mark. The machine-gunner who sprays the landscape with ten thousand bullets doubtless attains a high average among his fellows as a marksman if his shower of lead has accounted for ten men. And there is a fair chance that the average soldier, going through the entire war over there in Europe, and participating in battle after battle, plying his weapon in the aggre-

gate many hundred times, returned without having injured a single enemy.

These conclusions may seem rather startling, but they are justified by the most casual consideration of statistics showing the aggregate casualties of the war contrasted with the total number of combatants engaged. Millions on millions of bullets were fired, while at the very worst the casualties were numbered only in thousands.

These defects of efficiency in the use of the modern weapons are to some extent inherent in the characteristics of the weapon themselves. They have the defects of their qualities. A bullet must take an upward course if it is to travel far. If the sights of your gun are adjusted for a range of five hundred yards, and you aim directly at an enemy only one hundred yards away, you will send the bullet something like twenty feet above his head. The old-fashioned musket, with its relatively slow-traveling round bullet, sent the projectile more than one hundred feet in the air in order to carry it three hundred yards. The modern rifle propels the bullet much faster and so need not drive it so high in order to make it carry (in technical language it is said to have "flat trajectory"), but the path of every bullet is still a curve.

It follows that the marksman can not hope to hit any given target unless he first correctly estimates the distance of the target. Shooting on a range, over a measured and accurately known distance, at a motionless target, a soldier may become a crack marksman; but let the same marksman with the same gun attempt to hit a man who is running toward him at an unknown distance, and

the chances are about a hundred to one that he will fail utterly. If it were not so, every daylight offensive would fail as a matter of course, and to charge an entrenched enemy would be suicidal.

It is scarcely too much to say that the chief value of the modern rifle, in the hands of the average soldier, is to steady the nerves of the soldier himself, to make a noise that is somewhat disconcerting to the enemy, and to afford substantial base for a bayonet.

So clearly is its inefficiency as a shooting mechanism recognized that such experts as the late Captain Knyvett have recommended the substitution of a shotgun loaded with buckshot. Such a suggestion may sound farcical, but is in reality quite sensible. A trench line of soldiers armed with repeating shotguns loaded with buckshot, and instructed to aim always at the ground about fifty feet in front of them would make No-Man's Land a genuine slaughter field for any enemy that attempted to charge them. Supplement such companies of shotgun bearers with occasional individual riflemen who are judges of distance and can handle a gun as a big-game hunter does, and the efficiency of the infantry would be enormously enhanced.

In default of such individual efficiency, we have the machine gun—the most wasteful small arm ever invented, yet an absolutely necessary part of infantry equipment under existing conditions. The machine gun can spray bullets against a steel target in such gushes that their partially molten remains pour down and flow away like water from a cloudburst. Accurately directed against a human target, they would make a sieve of the human body almost before it had time to fall.

Accurately aimed, and swung back and forth along the lines of an enemy advancing in mass formation—as used, for example, by Kitchener's men at Omdurman—the machine gun is the deadliest weapon ever invented.

But—here again we view the other side of the shield—aimed inaccurately and spraying its bullets at random against a scattered or unseen foe, it offers doubtful competition in efficiency with the blunderbuss of the Middle Ages. And it is not for a moment to be compared with the flint-lock rifle of our Revolutionary forebears—when handled by said forebears.

THE MAN BEHIND THE GUN

All of which is intended, not as criticism of the machine gun, but as leading up to the assertion that the thing of prime importance is not so much the quality of the machine gun as the quality of the man behind the gun. Now and again one hears the question debated as to which one of the marvelous mechanical devices of present-day warfare had chief share in "winning the war." Was the deciding factor, it is asked, the machine gun, the airplane, the heavy artillery, or the U-boat destroyer?

The answer is a very simple one. Each of these mechanisms was a valuable accessory in winning the war; but the truly determining mechanism was that yet more wonderful machine, the human body; and in particular the human brain. The war was won by men whose bodies were guided by human intelligence. Mere numbers counted

for much, but individual efficiency enhanced the value of numbers. Many other traits besides marksmanship are required to make a good soldier; but, viewing the matter from the present standpoint, it would appear that marksmanship is among the essentials. If infantry action alone could decide a conflict, a company of Daniel Boones armed with muzzle-loading flint-locks would be worth a regiment of average soldiers equipped with modern rifles, even with half-a-dozen machine guns thrown in.

For the airman, marksmanship is even more essential. No one who is not a crack shot can hope to become an ace. Note, by way of illustration, that the lamented Lufbery, American Ace of Aces at the time of his death, won all prizes for marksmanship while with the army in the Philippines; and that Lieut. Fonck, the French Ace of Aces, had a record of bringing down six German planes in one day with the expenditure of only sixty shots all told from his machine gun. We are told that Lieut. Fonck participated in two hundred aerial battles without having any part of his machine hit by a bullet. Yet no doubt thousands of bullets in the aggregate were fired at him from enemy machine guns; and Lieut. Fonck himself, despite the record just noted, doubtless fired thousands of shots that failed to find a mark in the course of his hundred and fifty indecisive battles. The average air-scout shoots persistently, and hits nothing—not because he is a poor marksman, but because the task set him is superlatively difficult. The target is moving perhaps one hundred and fifty feet per second, and the marksman is moving just as fast probably in the opposite

direction. To average one hit in a hundred shots under such conditions would be super-marksmanship.

MECHANICAL PERFECTION VERSUS HUMAN SKILL

Having emphasized that aspect of the matter, however, let us revert for a moment to the machine gun as a triumph of human ingenuity—a mechanism that must be directed by human hands, to be sure, but which continues in action with a pertinency suggestive of voluntary—and altogether vicious—intention.

The secret of this "automatic" action is that the recoil of the weapon is utilized to eject the exploded shell, supply its place with a fresh one, and discharge this in turn.

It goes without saying that great ingenuity has been required to develop mechanism that will accomplish these ends expeditiously and unfailingly; but the principle involved is simply the familiar one that action and reaction are equal and in opposite directions. Stated otherwise, the gun is pushed backward as hard as the bullet is pushed forward. Every one who has ever experienced the "kick" of a hard-shooting gun will appreciate the practicalities of that principle. With the machine gun, the "kick" is harnessed, so to speak, and made useful.

Since a thousand successive charges of ammunition are exploded in the barrel of the gun at intervals of only a very small fraction of a second, the barrel will naturally become heated. How to cool it is one of the most important practical problems that confronts the maker of the machine gun. The problem is met, with some at least of the

modern machine guns, by having a barrel surrounded by a corrugated structure of aluminum, which radiates the heat rapidly into space. But at best the machine gun can not be fired indefinitely without a pause to permit the barrel to cool. It may be used continuously, however, for a long enough period as a rule to exhaust the available supply of ammunition and to spread a shower of bullets across any section of the landscape in which the enemy may be supposed to lurk.

A remarkable weapon, then, this machine gun; a useful accessory in winning the war, but after all only an accessory. The paramount and determining mechanism of warfare, as above suggested, is a far more complicated machine—the human body.

CHAPTER VI

ASPECTS OF MARITIME WARFARE

ON THE 22d of September, 1914, a British sea captain, sweeping the horizon casually from the bridge of his ship in the North Sea, noted that three war vessels were in view.

He observed that they were British vessels, and no doubt this gave him an added sense of safety; for his country was at war with Germany, and it would not have fared well with him had the warships that had thus come his way belonged to the enemy. But as it was all was well, and there was no occasion to observe the vessels more than casually.

A few minutes later the captain chanced to glance again in the direction of the warships, and was mildly surprized to observe that there appeared to be only two of them instead of the three that had first been noted. The observation was puzzling, but the captain appeared not to have been perturbed by it. When, however, after another interval of a few minutes, he again glanced in the direction of the warships, be observed that now only a single one was visible and now the comprehension came home to him that something was wrong.

He gave orders to have his own vessel turn in the direction of the missing warships, and made all haste to approach the scene of the apparent disaster. But even as he approached, the third warship was seen to be in difficulty, and long be-

fore the merchantman could reach it this vessel also foundered without apparent cause, and disappeared.

All that the merchantman could do was to rescue a small number of sailors, the larger part of whose companions had perished when their ships went down, or in the chilly water soon after.

Meantime no enemy had been seen, and the cause of the disaster to the three ships could be only matter of conjecture. As to this, however, there was no reasonable doubt. The vessels, it appeared, had been successively torpedoed; and as they were in the open sea where no mines could be laid, the only explanation could be that a submarine vessel or fleet of such vessels had attacked the cruisers and wrought their destruction while themselves remaining invisible. Such had indeed been the fact, and it was subsequently revealed that the craft that had accomplished this extraordinary feat was a small submarine of the German navy, designated the U-9.

This insignificant vessel—so small that it bore merely letter and number, not being dignified with a name—had single-handed attacked three relatively formidable cruisers, and with a single torpedo for each sent them successively to the bottom, without itself receiving any injury whatever, and probably without being observed by any member of the crews of its quarry.

It is said to have been the same submarine that similarly attacked and destroyed the British cruiser *Hawke* a few weeks later, when the vessel was sailing alone in waters which, so far as was known, were quite free of the enemy's warships. The destruction of the *Hawke* was a very notable

feat; but not to be compared, of course, with the unheralded attack on the three cruisers which resulted in the sinking of one after another—if the attack was really made, as claimed, by a single submarine.

The names of the cruisers were the *Aboukir*, the *Houge* and the *Cressy*. They were not warships of the newest and most formidable pattern, to be sure, but they were vessels of some significance, none the less; and there is no reason to suppose that their fate would have been different had they been warships of the most formidable size. For the modern torpedo, placed as were the torpedoes discharged by the U-9, constitutes a disrupting force that even the thickest plates of a dreadnaught can not withstand.

If there were any doubt as to that, the doubt was removed a few weeks later when the superdreadnaught *Audacious* was destroyed off the coast of Ireland by a mine; for there is no essential difference (except as to size) between the submarine mine and the torpedo discharged by a submarine vessel, each carrying the same type of explosive. Indeed, it was not at first known whether the *Audacious* had been destroyed by an anchored mine or by a torpedo discharged by a submarine.

A further demonstration of what the submarine boat can accomplish was given when, on the 12th of November, the British torpedo gunboat *Niger* was torpedoed and sunk by a submarine as it lay in the harbor at Deal. Here a German submarine had approached the British coast in the daytime and succeeded in passing through a mine field, presumably going under the mines, and had ap-

proached the pier at which the gunboat lay and discharged its projectile with telling effect, its presence having been quite unsuspected until its sinister purpose was effected.

Nor was the submarine itself seen even then. It was able, apparently, to make its way out of the harbor as it had entered, without encountering a mine and without being visible.

And in so doing it had accomplished an unprecedented feat, and necessitated the writing of a new chapter in naval history. It had shown what the submarine could do in the way of invading the harbor of an enemy, in defiance of mines and of the most elaborate equipment of coast defense, just as its companion craft, the U-9, had shown what might be accomplished, under favorable conditions, on the high seas.

A month later (December 13th) a British submarine, the B-11, performed an even more spectacular and daring feat by running under five rows of mines in the Dardanelles and sinking the Turkish warship *Messudiah,* retiring in safety, altho pursued by gun fire and torpedo boats. It had remained nine hours under water.

In the face of such achievements the most skeptical critic could no longer doubt that the submarine vessel is a war craft to be reckoned with in naval contests. Granted certain conditions, this little, frail, submersible shell might engage the most powerful battle ship on terms of something more than equality. An enemy that can approach unseen and can remain invisible even while making its attack, yet which carries a weapon capable of destroying the most powerful battle ship at a single blow, is one that must inspire respect not

unmingled with fear. It supplies one of two incalculable factors that make it impossible to predict the outcome of naval battles that otherwise might seem clearly predetermined.

The other uncertain factor referred to is, of course, the airship, about which we shall have more to say presently.

Meantime it should be observed that there is really nothing surprizing about the successes of the submarines just outlined. The possibility of constructing submarine vessels that could blow up warships was demonstrated more than a century ago by Bushnell and by Robert Fulton. Submarine craft were used in the American Civil War, and in one case successfully, when the Federal ship *Housatonic* was torpedoed and sunk in Charleston Harbor on the night of February 17th, 1864. And in recent years the submarine has been so perfected as to become a reasonably safe and thoroughly manageable craft, the possible efficiency of which has been demonstrated again and again in nautical tests and sham battles.

It had been amply demonstrated that the present-day submarine is thoroughly seaworthy, and it was familiarly known that the periscope, through which light is reflected into the submarine, enabling its officers to see what is going on in the air above them, is so small as to be practically invisible from the deck of a ship under ordinary conditions of surface waves, even when so near that a torpedo might be discharged with almost unfailing aim.

And yet, thanks to the conservatism of the generality of mankind, it is probable that the demonstrations of the capacities of the submarine in

actual warfare that were made in the early stages of the great European conflict in the fall of 1914 came as a surprize to most laymen, and to a very large number of naval experts as well. Notwithstanding the showing made by the submarine in times of peace, there is no doubt that skepticism regarding their actual capacities as war craft was quite general, and nothing short of the actual demonstration in war of their efficiency could dispel this skepticism.

But after one submarine had sunk four warships on the high seas, and another craft of the same type had entered a fortified harbor and sunk a war vessel at its pier, there remained little opportunity for skepticism. The long-despised submarine had at last come to its own. The predictions of its advocates were verified.

A new chapter of naval history had been written, and again the question became pertinent as to whether the steel-clad leviathan, grown to such startling dimensions in the most recent decade, does not represent a type that must soon be superseded. At least it must be given additional protection—perhaps by the use of a second shell of armor a few feet inside the hull.

CAPACITIES AND LIMITATIONS OF THE SUBMARINE

It was clearly recognized even before the war that the greatest defect of the submersible vessel was its relative lack of speed. It is obvious that in such a craft there is great need of conserving the supply of oxygen, and of course it is impossible to utilize large quantities of fuel without drawing correspondingly upon the atmosphere for oxygen. Also there results a corresponding vitia-

tion of the atmosphere through the production of combustion. Moreover, space is at a premium, and both machinery and fuel must be kept at a relative minimum.

Most submarines hitherto, in recent years, had been propelled by gasoline engines when working at the surface, and by storage batteries when submerged. The crude early submarines were propelled by hand, but of course vessels of this type would be as much out of date in a modern navy as would rowboats at the surface. Attempts had been made to utilize steam as the motive power, but this has obvious disadvantages.

It was reported in the early days of the war that the Diesel engine had been used as the motive power for submarines, and it seemed as if this might be almost an ideal motor. It uses crude oil, which is introduced into the cylinder under high pressure and exploded there by the heat of compression, and it develops a high degree of efficiency. With the use of these engines it seemed probable that the speed of the submarine, when operating at the surface, might be increased greatly beyond the former maximum of sixteen to eighteen knots per hour.

When the submarine operates at the surface a part of its power may be utilized to charge its storage batteries, which supply the motive power when the apparatus is submerged. Unfortunately storage batteries are very cumbersome, and there can be no doubt that the development of an improved type of storage battery would greatly increase the efficiency of the submarine, by increasing its power, which is of course equivalent to increasing its speed.

It was urged that if the submarine could be made to double its maximum speed of eleven to twelve knots per hour when submerged, its value as a fighting craft would be enormously enhanced, as it would then be able to overtake a battle ship under full headway in the open sea. There would seem to be nothing inherent in the nature of the problem to prevent a development of submarines having speed equal to that of the fastest cruisers. But we shall see that the problem was not solved during the war.

THE FAILURE THAT SANK 5,000 SHIPS

When the permanent annals of the great war are written, an outstanding feature, as a matter of course, will be the record of the tremendous havoc wrought by the submarine boats. But another outstanding feature, paradoxically enough, will be the record of the essential failure of the submarine campaign. The crucial test of the U-boats' efficiency was their capacity to prevent the shipping of soldiers and supplies from America. The crossing of two million soldiers with a loss of less than three hundred individuals is the all-sufficient answer.

That record tells of the essential failure of the U-boat campaign. I shall analyze this failure in a moment, but first let us examine briefly the other aspect of the story, telling of the appalling destructiveness of the U-boats, notwithstanding their ultimate failure to meet the expectations of the ruthless projectors of this new type of warfare.

Official figures for this estimate were supplied by Sir Eric Geddes, head of the British Admiralty, in a public speech. Taken by itself, the record is

nothing less than appalling. It appears that the losses to British warships were approximately 230, with an additional loss of 450 auxiliary warcraft, such as mine-sweepers and trawlers, making a total of 680. Meantime merchant ships showed a total loss of more than twenty-four hundred, representing a gross tonnage of nearly 7,750,000.

This is for British craft alone. Only approximate estimates are available for the losses to the British Allies and neutrals; but these are said to be something like half the total of warships and seventy-five per cent. of the loss to British merchant ships. In round numbers, then, the world's total loss in warships and auxiliary craft was somewhere in the neighborhood of one thousand vessels; and the loss to merchant ships about four thousand; a total aggregate loss of not far from five thousand vessels.

We gain a more vivid idea of what this means if we reflect that such a cohort of vessels would suffice to patrol the ocean from Newfoundland to Ireland with approximately three vessels to the mile. If the total loss in tonnage were distributed among vessels of the size of that in which Columbus made his first voyage across the ocean, there would be enough of these vessels placed prow to stern in single line, near enough to permit a short gangplank to pass from ship to ship, to make a pontoon bridge across the Atlantic. If this pontoon bridge were broken up, and the ships making it redistributed five abreast, allowing for each group a leeway of 762 feet (the length of the *Lusitania*), the ships thus grouped would make an unbroken cordon from America to Europe.

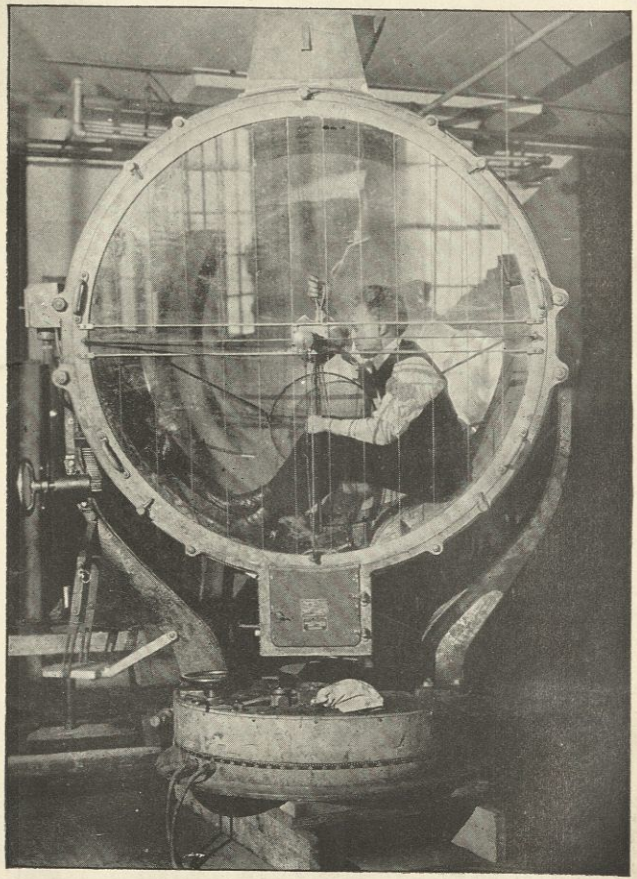
Viewing the situation from another angle, it

appears that throughout the long, dreary course of the war, month in and month out, a ship was sunk, on the average, each eight hours. Think of it! Each and every night during those four years and more, in the eight-hour period of your sleep, a helpless ship foundered; during each eight-hour working day, another; and in your intervals of working and sleeping, a third; usually with loss of live, often with sacrifice of scores or hundreds of non-combatants.

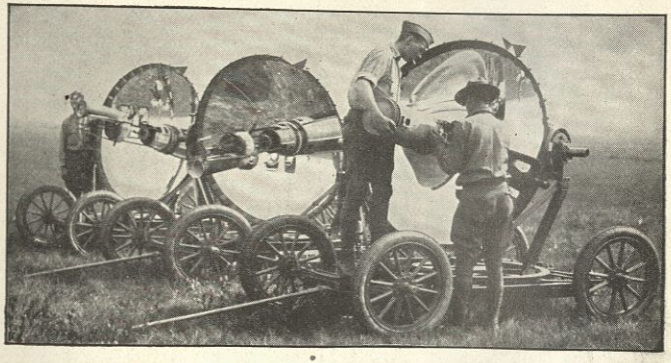
It appears that the average size of the British merchantmen sunk in this ruthless warfare was 2,200 tons—a craft of altogether respectable bulk even in this day of leviathans. Some day, perhaps, we shall know, at least in round numbers, the aggregate loss of life that has resulted. Some day we shall have at least general estimates of the loss in mere monetary values. Some day attempts will be made to salvage a portion of the treasure that lies at the bottom of the ocean—fabulous beyond computation or conception, but doubtless for the most part irrecoverable. All that, however, is for the future.

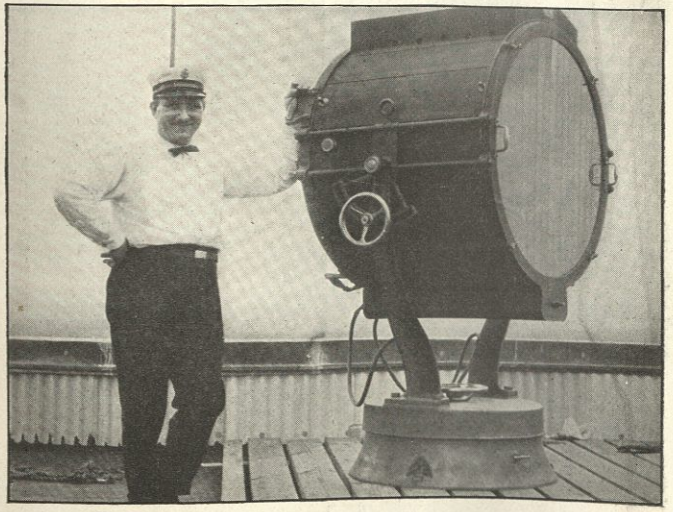
WHY THE SUBMARINE FAILED

Meantime there is timely interest in observation and analysis of the other aspect of the submarine story. How has it chanced that a weapon so malignant and so effective as the submarine showed itself to be—a weapon that has accounted for not far from a thousand warcraft and something like four thousand merchantmen—should have proved utterly ineffective when directed against the transports that have carried our boys to Europe? The

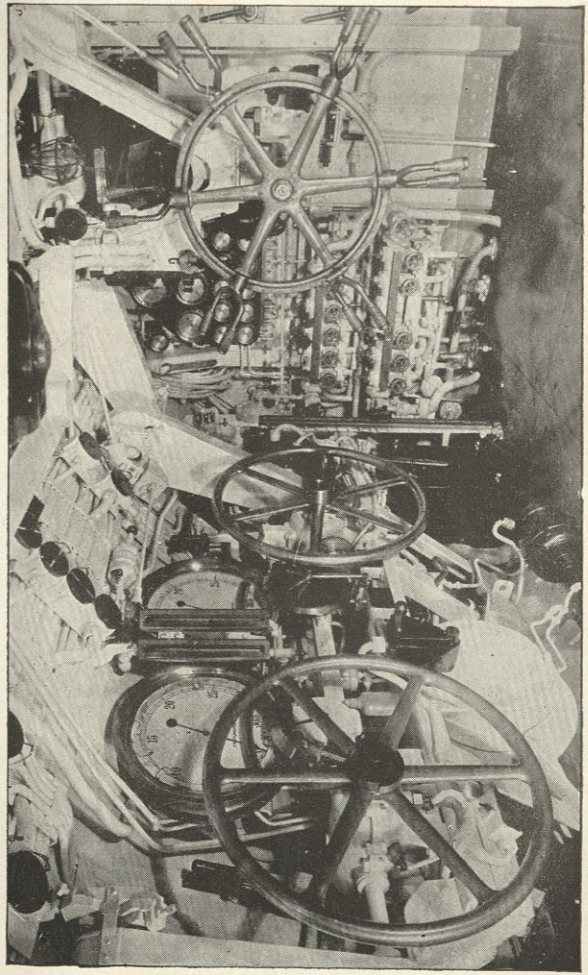


SEARCHLIGHT INVENTED BY ELMER E. SPERRY SAID TO BE THE LARGEST EVER CONSTRUCTED. IT CAN BE OPERATED BY DISTANT CONTROL

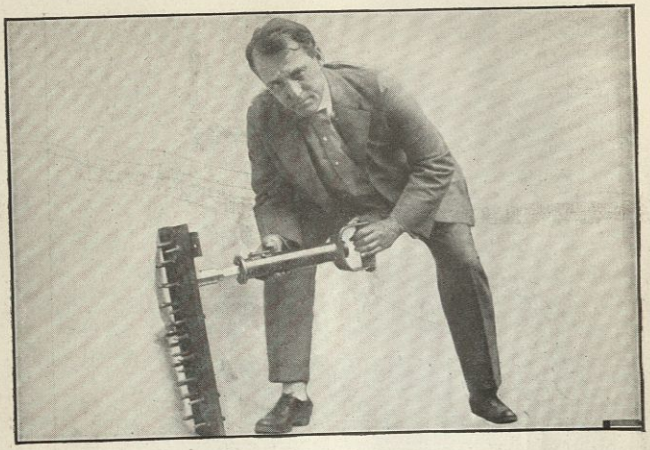




GIGANTIC SEARCHLIGHTS USED TO REVEAL AIRCRAFT AND TO ILLUMINATE AVIATION FIELDS



COMPLEX INTERNALS OF A SUBMARINE



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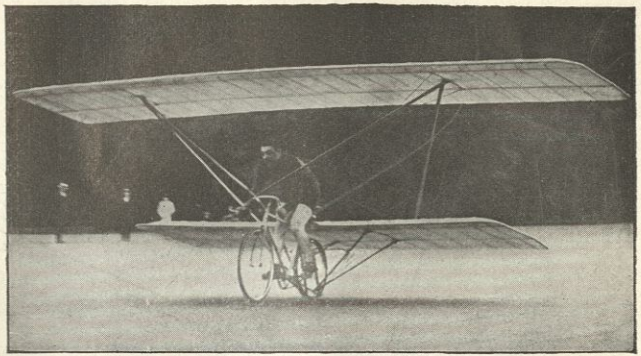
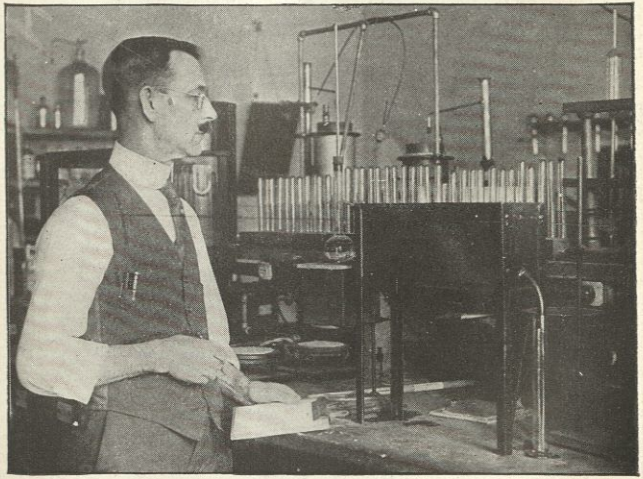
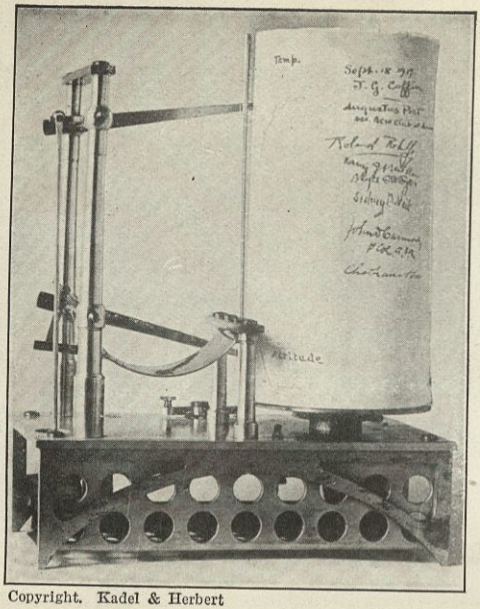
DR. MILLER REESE HUTCHINSON AND A MODEL OF HIS "TWO-HUNDRED-MILE GUN" (ABOVE), AND A LIGHT MACHINE-GUN INVENTED BY GEN. JOHN T. THOMPSON





GABRIEL POULAIN AND HIS MAN-PROPELLED "CYCLOPLANE," AND ARTHUR DRAPER OF THE U. S. BUREAU OF MINES TESTING MOTOR FUELS



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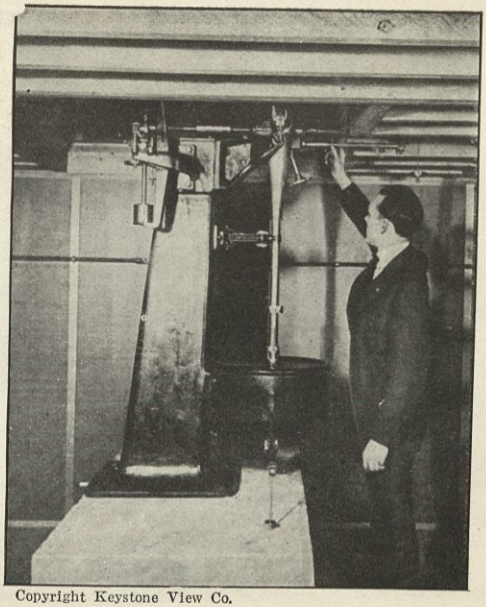

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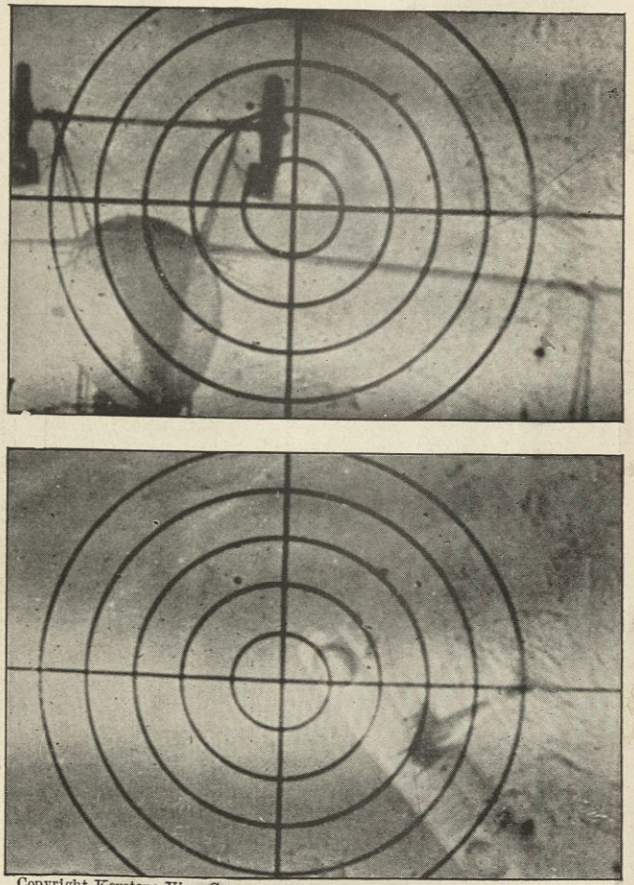
BAROGRAPH THAT RECORDED THE 34,910-FEET ALTITUDE FLIGHT OF ROHLFS (LEFT), AND BALANCE FOR TESTING WIND-RESISTANCE OF AIRPLANE MODELS

A MAIL-CARRYING AIRPLANE READY FOR ACTION



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RECORD OF AN AIRPLANE DUEL WITH CAMERA-GUNS. THE CROSSED LINES AT THE BULLSEYES SHOW WHERE THE BULLETS WOULD HAVE GONE, IN EACH CASE MISSING THE AIRPLANE TARGET

thing seems paradoxical; but it is a paradox that is susceptible of fairly clear explanation.

It goes without saying that the escape of the American transports was not due to any lack of effort on the part of the enemy. Nor, it may be added, was there any considerable element of luck involved. The escape of the transports, enabling them to carry out their herculean task of transporting a vast army of Americans to Europe, was one of the most striking tributes to the efficiency of the governmental powers that had charge of overseas transportation. They had the prescience to take cognizance of the U-boat conditions as they were, and to meet these conditions in a manner the logicality of which was demonstrated by results.

Part of this was accomplished by an elaborate system of convoys, in which exceedingly speedy destroyers patrolled the waters on all sides of the fleet of relatively slow merchantmen. Their vigilance made it practically impossible for the U-boats to approach within striking distance without extreme peril to themselves. The periscope of the U-boat was a thing of "low visibility," yet it had small chance of escaping the search of the hundreds of eyes that were constantly on the lookout. So the safety of the transports convoyed by the destroyers and other fast battleships is readily comprehensible.

The U-boat, of course, made no attempt to compete with the warships of the surface in open exchange of hostilities. It is at best a frail shell of a craft, and its only safety was in diving beneath the surface. A method was found of assailing it even there with the so-called depth-bomb. This

is merely a charge of high explosives calculated, as the name suggests, to explode only at a considerable depth, being cast overboard from the destroyer as nearly as may be in the region where the periscope of the U-boat was observed to submerge. If the explosion takes place in the immediate vicinity of the submerged craft, the frail shell is crushed in with disastrous effect.

The efficacy of the method depends on the fact that water is virtually incompressible. The exploding bomb exerts a terrific thrust in all directions. The force of the thrust diminishes as the square of the distance. The impact, for example, against the side of a U-boat ten yards away would be twenty-five times that on a craft fifty yards away. So there is an obvious premium on placing the bomb near the submarine. The exact distance at which it may be effective depends, obviously, on the size of the bomb itself. The expanding gas can escape, ultimately, toward the surface of the water; but at the instant of explosion, in a body of water that is absolutely unyielding downward and laterally, the thrust exerted is like the impact of a battering-ram, against which the U-boat has no defense whatsoever.

It would be mere foolhardiness on the part of the U-boat commander to venture into the midst of a fleet of transports convoyed by destroyers; so even the slowest of merchantmen, thus protected, crossed the ocean in safety. Perhaps it is not so generally known, however, that numbers of fast transports, carrying in the aggregate a vast body of soldiers, made the transatlantic journey quite without convoy. Such was nevertheless

the fact; it may indeed be open to question whether a fast ship was not quite as safe when sailing thus by itself as if it were surrounded by a galaxy of destroyers. Such would not be the case, of course, if the ship were to follow a prescribed course, and to move straight ahead for long stretches as ships were wont to do in normal times. Under such conditions the submarine might lie in wait and secure its victim with certainty. But the fast ship carrying soldiers or supplies and depending on its own speed for safety did not follow such a course as this. Instead of keeping to the charted path, it had the whole ocean for its course, and no one but the commander knew precisely what part of this boundless tract would be traversed. Moreover, this ship did not sail for any great length of time in a single direction, but periodically shifted its course this way or that.

The obvious effect was to make the U-boat's search for such a ship comparable to the proverbial search for the needle in the haystack. Nothing but sheer accident of greatest unlikelihood would bring the ship at any given time within striking distance of the spot where a U-boat chanced to lurk. Even should the U-boat sight the ship in the distance, and steer for a location apparently calculated to intercept it, the ship would probably swerve from its course before that location was reached in such a way as to carry it wide of its unseen would-be assailant.

To make the matter altogether clear, it must be reiterated that the U-boat was essentially a slow craft. The utmost speed on the surface of the pre-war type was scarcely more than fourteen

knots per hour—only about two-thirds the speed of a fast transport; and the more recent U-boats were not greatly improved in this regard. It followed that the submarine must sight its intended victim while it was approaching in order to stand the slightest chance of getting near it. A transport that is already abeam will widen its distance from its assailant with every turn of its propellers. When the submarine is submerged, it progresses still more slowly, and its task of intercepting the fast transport becomes proportionately hopeless. And of course the submarine dare not make its attack without being submerged, since the transports are armed with guns of destructive caliber manned by marines who are famed as marksmen.

Even should sheer luck favor the submarine and bring it abreast a transport at a distance of, let us say, one mile, it does not at all follow that its purpose of destruction will be consummated. In the first place, there is no probability that the periscope of the submarine will escape detection at such a distance unless the sea is rough; and obviously a rough sea must make it extremely difficult for the submarine to project its torpedo with accurate aim. Aiming a torpedo with the aid only of the view attainable through a periscope is at best a rather haphazard procedure. The exact distance of the ship can only be guessed; the grotesque markings with which it is camouflaged make it difficult with this uncertain view in a doubtful light to determine accurately the place at which to aim; and aiming at best consists only of pointing the U-boat itself somewhat roughly in the direction of the target.

But this target, you say, is after all a ship perhaps five hundred feet in length. Surely it can not be difficult to hit so large a mark. In making that estimate, you overlook the essential conditions. The ship is indeed perhaps five hundred feet in length; but it is moving forward at the rate of at least twenty knots per hour. In other words, it is changing its location in totality every eighteen seconds. Meantime the torpedo that is directed against it is in effect a miniature ship, progressing with relative slowness through the water. It has no such speed as a cannon-ball; the utmost that can be expected of it is progress at the rate of about forty miles per hour, and this only for a short distance.

If the ship aimed at is a mile away, the torpedo will require perhaps two minutes to reach it; and during those two minutes the ship will have changed its location by two-thirds of a mile, or seven ship-lengths. It follows that if the U-boat marksman were to aim with accuracy directly at the ship, his torpedo would pass two-thirds of a mile in the wake of its intended victim, coming not much nearer than when it started.

Obviously the torpedo that is to find its mark must be directed far in advance—aimed not at the ship itself, but at an open space of water estimated to be about two-thirds of a mile in front of the ship's prow. The ship's distance must be accurately estimated, and the camouflage markings make this doubly difficult, as they are calculated to deceive the observer as to the dimensions of the vessel. This is perhaps the thing chiefly accomplished by the weird stripings and checkings of the camouflaged vessel. If one torpedo in ten

found its mark under such conditions the marksmanship would be extraordinary, even tho the ship were to keep its course unchanged, oblivious of the U-boat's presence. Granted actual conditions, under which observers on the ship will doubtless detect the torpedo as it approaches, and be able if desirable to veer the ship from her course, the chances of the torpedo taking effect are further minimized. And even when the projectile is headed in exactly the right course, it is within the possibilities that a well-directed shot from the ship may strike it and explode it harmlessly at a distance,—tho I am not aware that this fact was ever actually accomplished.

When all these conditions are visualized, it no longer seems astonishing that transports were able to carry out soldiers by hundreds of thousands to Europe in defiance of the U-boats. It is scarcely too much to say that a transport, skilfully handled, had little to fear from U-boats of the pre-war type. It must be recalled, however, that a single modification in the U-boat, were it attainable, would have changed the conditions utterly. The safety of the transports, as above predicated, was conditioned entirely on the U-boat's lack of speed.

If German ingenuity had been able to devise a U-boat having the speed of the average destroyer, our transports would have been at the mercy of the submarine.

The destructive possibilities of small, speedy craft have been illustrated by the forays made by Italian torpedo-boats on the enemy ships in the Austrian harbors; and in a less spectacular way by the habitual activities of the destroyers that convoy the merchant fleet, which again and again

have been able to dash to the spot where a submarine periscope has been seen to submerge in time to drop a depth-bomb before the slow-moving, submerged craft could propel itself to a safe distance.

The great danger that the marine warfare of the future must face is that submarine boats will some day be produced that are capable of the speed of the fastest craft that plow the surface. When that time comes, battleships of the present type will be as obsolete as the wooden ships of Lord Nelson; and it will be possible to transport soldiers overseas only in airships. It is fortunate indeed for civilized humanity that the problem of making a fast submarine has hitherto baffled the inventor.

THE EARS OF A SHIP

It should be added that the modern ship has an additional equipment that aids enormously in giving it protection against submarine attack, in that it is supplied with a pair of ears that enable it to detect not only the proximity but even the general direction of a would-be assailant.

Sound travels through the water about four times as fast as it travels through the air. So the ears of a ship are naturally adjusted below the water line. You may call them submarine signal apparatuses if you prefer; but an apparatus designed solely to receive and register the vibrations of sound is certainly entitled to be called an "ear" in every-day speech. And such an apparatus the up-to-date ship carries adjusted at either side of its prow, well down toward the keel. The navigator of a vessel thus equipped

is kept informed as to many happenings of which otherwise he would have no knowledge.

In a dense fog, for example, the ears may tell him of the proximity of another ship, thus on occasion enabling him to avoid danger of collision. The experienced listener may be able to name the ship that makes the sounds he hears, for every vessel, it appears, has a personality expressed more or less definitely in the sounds made by its propellers.

The ears of the ship may even bring a record of the proximity of a silent thing, like an iceberg. In this case, sounds sent out by the ship itself come back as echoes, revealing that there is an iceberg to port or starboard, as the case may be. Thus the up-to-date ship may escape such a disaster as that which overtook the *Titanic*.

The ship's ears are of course connected by wires with telephone receivers in the navigator's cabin. Here there will be, also, as a matter of course, receivers from a radio apparatus. The two working together may give the navigator information not merely as to the direction but as to the precise distance of another vessel, provided that vessel sends radio signals and submarine signals simultaneously. The radio signals come to the listener instantly (traveling 186,000 miles per second), whereas the submarine sounds travel only about 4,800 feet per second. A stop-watch records the difference in time. Multiplying the number of seconds by 4,800, the navigator has the answer in feet.

A popular form of ship's ear is one invented by Professor Reginald A. Fessenden. It includes a circular disc of metal which is fitted into a hole

of just the right size cut in the "skin" of the ship. The steel disc, altho about three-quarters of an inch thick, is made to vibrate by the passage of alternating electric current, and it is therefore called an oscillator. In vibrating it produces a shrill note, and thus signals other ships. Meantime, being connected with vacuum tube amplifiers, it receives and makes audible submarine sounds from miles away.

In war time, the ship's ear was a submarine detector, with no substitute. In peace-time it cooperates with the radio apparatus in lessening the dangers of sea-voyaging. To meet this defensive mechanism, the submarine boat of the future must find a means of propulsion that does not involve the revolving of a tell-tale propeller. A large order, that, tho probably not beyond the possible reach of inventive ingeunity.

It remains to be said, however, that the entire problem of the submarine is far less significant than it would be had not the development of far-flying, weight-carrying airplanes and helium-filled balloons given maritime warfare an entirely new aspect. The surface ship as a fighting mechanism appears to be obsolescent. Even as a transport, its significance is greatly minimized. The route of the future is overhead.

BREAKING THE BATTLESHIP'S NOSE

When the Conference on the Limitation of Armaments in Washington determined to scrap a certain number of battleships, there were onlookers who felt that the procedure had about the same significance in its bearing on future wars

that would attend an order to scrap all birch-bark canoes.

As a "moral influence" and what physicians would call a "placebo" for pacifists, the scrapping of the cumbersome craft might serve a fine international purpose. As an anti-war measure, it would have precisely no significance at all.

The force of the suggestion is illustrated by the report issued late in 1922 of the progress of the work of construction of the fighting machine that has broken the battleship's nose, so to speak. The new agent of destruction is called an "airplane carrier."

Our navy already had one airplane carrier, the U. S. S. *Langley,* rebuilt from the old collier, *Jupiter,* the first vessel of the navy to be equipped with the electric drive. The two aircraft carriers being built (1923) from material originally planned for battle cruisers are much more formidable. Each of these is a craft 850 feet long, designed to attain a speed of 33 knots (not far from 39 miles) an hour. Four electrically driven shafts will develop 180,000 horse-power—almost seven and a half times more than the propelling energy of the *Maryland,* which represents the navy's speediest existing type of ships.

It is officially stated by the General Electric Company, at whose plant at Schenectady the equipment is being developed, that the generating plant in each of these vessels will develop electricity enough to supply the entire electrical needs of a city the size of Boston.

But the new vessel will not be a battleship in the old sense of the word. It will carry no big turrets and gigantic guns. Its fighting equipment

will consist of airplanes. Its missiles will be sent through the air, and their range is not a mere ten or fifteen miles, but a hundred, or it may be five or ten times that.

The top deck is flat, for receiving and launching airships. The hold is a giant hangar for the storage of airships. The ship has a superb radio equipment, partly for the control of pilotless airships.

It will be able to send out airplanes, without pilots but under absolute control, laden with bombs that can be launched against an enemy ship or coastwise city, with more than the accuracy of cannon balls, and with a deadliness of effect far exceeding that of the most terrific broadside ever fired by the sixteen-inch batteries of a dreadnaught.

This is not prophecy. It merely predicates what could be done to-day were war to break out between big maritime powers.

CHAPTER VII

WHY THE ZEPPELIN FAILED

PERSONS fond of a paradox may find interest and amusement in considering the history of the balloon in the great war. It will be recalled that the Germans had been actively engaged for a decade and a half before the war in the perfection of gigantic airships which were expected to give them absolute supremacy in a new type of warfare. The Zeppelin, as the dirigible craft was called in honor of its chief developer, had come to be a familiar object to the eye of the European traveler. It had proved capable of traversing the upper atmosphere under control in defiance of air currents and of returning to the earth at a designated spot at the option of the navigator. Passenger service had been established along the Rhine and the general status of the Zeppelin gave a certain warrant to the claim that the conquest of the air had been accomplished.

There is no question that the Germans in projecting their war campaign set great store by the Zeppelin. Paris and London were within range of its activities; there was talk even of transoceanic possibilities; and the opportunity to use the new weapon in a campaign of "frightfulness" seemed boundless.

Unquestionably the populations of French and English cities were terrorized by the prospect.

But it chanced, as everyone now knows, that the Zeppelin had one inherent and radical defect that made all these prophecies nugatory. It is true

that raids of the airships were made over the Belgian cities first and then across the Channel, and bombs were dropped with destructive effect even in London. But so hazardous did this procedure prove for the Zeppelins themselves that long before the war was over it was obvious even to their most enthusiastic advocates that they had no such value as had been ascribed to them even in promulgating a reign of terror.

The one universal and inherent defect referred to was the fact that the Zeppelin depends for its buoyancy on having its gigantic body inflated with hydrogen gas; coupled with the fact that hydrogen gas is inflammable. The hydrogen atom has a great affinity for oxygen. Given a fair opportunity, it unites with oxygen with explosive force; so the tiniest spark introduced into any part of the Zeppelin's great gas-bag leads to an utterly disastrous conflagration.

Wherefore the all-sufficient answer to the Zeppelin was promptly found in anti-aircraft guns that hurled explosive shells into the upper atmosphere, and in airplanes equipped with explosive bombs and, ultimately, with machine guns firing incendiary bullets.

So soon as these defensive measures were perfected, the Zeppelin ceased to have conspicuous value or significance in the war. All the calculations of the military authorities, and the enormous expenditure of money in the perfection of the dirigible airship, had gone practically for naught.

THE OLD-FASHIONED BALLOON COMES BACK

But now appears the essence of the paradox. Whereas this new and highly scientific instrument

of aerial conquest had utterly failed, the old-fashioned, unscientific, commonplace balloon—the balloon of Napoleon I, of our Civil War, of Paris in the siege of 1871—proved one of the most important and effective aids to warfare as finally developed along the trenches, and was very much in evidence up to the end of the conflict. In the all-important work of reconnoitering the position of the enemy, localizing his batteries, "spotting" the shots and securing absolutely accurate range for the laying down of a barrage, the old-fashioned balloon proved an incomparable and indispensable companion of the artillery service.

Everywhere along the battle line, on both sides, a mile or two back from the trenches, could be seen balloons performing these services; and the destruction of such balloons was one of the perilous tasks to which the airplane pilots of both sides constantly directed their efforts, and in which many of them gave up their lives.

It is, as I said, a curious paradox that this old-fashioned type of balloon should have proved so effective and so indispensable a part of the military equipment in a war marked by novelties in the way of scientific mechanisms. The failure of the Zeppelin might have been predicted, and was indeed predicted by those of us who pinned our faith in the heavier-than-air flying machine; but the success of the old-fashioned balloon could hardly have been anticipated by anyone who did not accurately preconceive the conditions of warfare as finally developed. And it may well be doubted whether anyone did preconceive these conditions with a large measure of prophetic accuracy.

The essential function of the balloon proved to be not the work of bomb dropping or other means of actively offensive warfare, but the passive function of reconnaissance. It was, in effect, one of the eyes of the artillery,—the other eye being the airplane. The balloon that performed this service was spoken of as a "captive balloon," because it was held securely at anchor by a cable let out from a windlass (operated usually by the hands of the artillerymen) and thus maintained practically stationary at a known elevation. The occupant of the basket suspended from the balloon was equipped with a triangulation apparatus for measuring distance, and with a telephone connected by wire with the earth. He might or might not have a machine gun with him to enable him to take a shot at an enemy airplane on occasion; but this in any event would be an altogether subordinate part of his equipment, for his main function was not to fight directly but to enable the guns of the battery below to place their shots effectively.

Under these circumstances, the balloon observer was obviously in the position of the lookout man in the crow's-nest of a ship or of the primitive warrior who climbed a tree in order to gain a distant view of his environment. But the balloon has obvious advantages in that it can rise to an indefinite height. If the view at a given elevation is not all that could be desired, nothing more is necessary than to pay out an additional length of cable and the observer is carried to a higher elevation.

It was very essential, however, that the manipulators of the cable should keep tab on their work,

to the effect that certain of their companions should know at all times the precise elevation at which the balloon is resting. These were the men operating the anti-aircraft guns whose function it was to protect the balloon by placing a barrage of exploding shells at a certain distance above it and in the event that an airplane made an attack with attempt to destroy the balloon. Such a barrage, altho not absolutely effective, made it perilous for the airplanes. But it is obvious that unless accurately placed it might make it even more perilous for the occupant of the balloon. Occasionally it happened, as is recorded, that the operators of the anti-aircraft guns miscalculated or forgot the height of the balloon and sent their explosives scurrying into the body of the apparatus they wished to protect.

Under such circumstances, or in the more usual event of an airplane attack in which the pilot succeeded in sending an incendiary bullet through the body of the balloon, causing it to burst into flames, the observer in the balloon-basket had no resource but to leave what had now ceased to be a coign of vantage and spring out into the air, trusting to his parachute—dating from the 18th century—to bring him safely to earth. Confidence in the parachute, it is recorded, was almost always well placed, and injury seldom resulted from such a descent.

The balloon itself, on the other hand, was as a matter of course utterly wrecked by the conflagration that resulted from the penetration of a single incendiary bullet. Here, as with the Zeppelin, vulnerability hinged on the use of an inflammable gas to give the apparatus buoyancy.

And inasmuch as the balloon was a large and inviting target, helplessly anchored in the sky, it is not strange that venturesome airmen were constantly pot-hunting for this particular type of game. It is obviously desirable, from the standpoint of the enemy, to put out this obtruding eye of the artillery whenever possible. So the business of war was constantly enlivened by a game of hide-and-seek between airplane and balloon, in which the only salvation of the latter lay in the facility with which it could be drawn back to earth or, if the emergency were exigent, collapsed in the air, by evacuation of its gaseous contents, and thus permitted to drop rapidly to terrestrial safety.

The records tell of the destruction of considerable numbers of these captive balloons on both sides; so the success of this arm of the service was largely due to the facility with which new balloons could be constructed. The captive balloon is, speaking in military terms, a comparatively inexpensive affair. Scores or perhaps hundreds of them could be built for the cost of a single Zeppelin. Nevertheless it is obvious that the extreme vulnerability of the balloon is an element that mars its efficiency, and the question naturally arises as to why an inflammable gas was used to inflate the balloon, inasmuch as the danger of conflagration constituted the one salient weakness.

HYDROGEN AND HELIUM

The answer, as might be foretold, is that no gas was available that could be substituted effectively for hydrogen or one of its explosive com-

pounds. As a matter of course, chemists have endeavored to produce a gas that will meet the conditions of lightness essential to give the balloon buoyancy without being inflammable. But it requires only the most elementary knowledge of chemistry to show how nearly hopeless such a quest must be. The essential difficulty resides in the fact that the one indispensable quality of a balloon gas must be lightness. The balloon rises by its own buoyancy, as a cork rises in water. Obviously it will not rise unless it displaces a bulk of air heavier than itself.

Meantime it chances that there is only one common element which is gaseous at ordinary temperature that is lighter than the atmosphere,—this element being hydrogen.

Indeed, the only elements having a lower atomic weight than nitrogen and oxygen are boron, carbon, familiar as solids in various combinations; the somewhat less familiar lithium, and beryllium; and the rare radium-product, helium. Of these, carbon alone offers material for gas-making in combination with hydrogen; but the compounds are highly inflammable, some of them being familiar in the form of illuminating gas.

Helium is the lightest known substance except hydrogen; and it exists in the atmosphere as a "minor gas," and in various mineral ores. Unfortunately it is isolated with difficulty and until recently only a few hundred cubic feet of it were in existence free from admixture. Methods of isolating helium on a large scale were sought by the military authorities, and the problem was solved in this country; but the total quantity of helium gas available when the armistice was

signed would not suffice to inflate a single large dirigible.

For the rest, the minor gases of the atmosphere are all relatively heavy, argon being two and a half times as heavy as oxygen, and zenon having an atomic weight of 128 (the atomic weight of oxygen being 16). Meantime chlorine, about the only uninflammable gas that would be readily available, is more than twice as heavy as oxygen.

So it appears that the inherent difficulties encountered by the chemist in the endeavor to produce a gas that shall be at once light and non-inflammable are exceedingly perplexing. Fortunately, however, we are not dependent upon the chemist alone for a solution of the problem. The study of pneumatics falls well within the scope of the physicist as well; and once we come to consider gases in their physical rather than in their chemical relations, a possible solution of the difficulty becomes manifest. Indeed, we are confronted with the rather startling conclusion that the problem is no problem at all, inasmuch as it was solved by the very first men who ever made a balloon, away back in the eighteenth century.

THE HOT-AIR BALLOON

The men in question were the Wright brothers of their day. They were Frenchmen named Montgolfier. They produced a balloon which, defying gravitation and all of the predictions of the scientific critics, mounted into the air and soared away, like a gigantic soap bubble. And they used no hydrogen or other inflammable gas to inflate their balloon, which to contemporary

observation seemed as wonderful as the airplane of the Wright brothers seemed to us a decade ago. Yet their balloon was a lighter-than-air mechanism—an inflated gas-bag—the direct prototype of the balloons of the present day about which I am writing. Their first balloon carried no passengers; but presently animals—a duck, a cock, and a sheep as the first aeronauts—and then men were sent up to brave the perils of the atmosphere,—an extremely hazardous procedure, it was supposed, inasmuch as many theorists had contended that man could not live at an altitude of more than a few hundred feet.

An interesting story might be told of the voyages of these early balloons, made under patronage of King Louis XVI in the later decades of the eighteenth century,—how they carried passengers from one part of Europe to another, even delivering mail across the English Channel from France to Britain, and how some of the early aeronauts lost their lives by being blown out to sea. But the essential point, in the present view, is that the very first of these balloons were operated by a gas that was not hydrogen and was not inflammable.

This gas was the same that gives buoyancy to the familiar soap bubble, namely, heated air. The Montgolfiers arranged their gas-bag with a torch at its mouth, so that the air within it was heated. Heated air expands and becomes proportionately lighter; presently it fills out the great sack, because its expansive pressure is greater than the pressure of air at ordinary temperature; and the bag thus expanded being lighter than the displaced bulk of air has buoyancy.

The feat that the Montgolfiers performed with their hot-air balloon has been duplicated thousands of times. Most Americans who have ever attended a county fair have seen a similar balloon operated in this primitive fashion. No knowledge of physics or chemistry is therefore necessary to demonstrate that a gas is available which is non-explosive and yet which can be used to inflate a balloon effectively.

It is true that the air would need to be heated to a high degree of temperature to make it rival hydrogen gas in lightness and buoying efficiency. It is true also that to give a balloon stability for a considerable period of time something more would be necessary than the kerosene-soaked ball of twine that usually does service in the inflation of the county-fair balloon. But fortunately modern science does not restrict us to such primitive means. Methods have been devised of heating air rapidly by passing it between metal plates—in the Svea caloric engine, for example—and it would be readily possible with an electrical device to provide in this manner for the needs of a captive military balloon. The balloon would then be immune to the attacks of the airman with his incendiary bullets. So obvious would be the advantages that we may take it for granted that hot-air balloons will be part of the equipment of armies of the future, if indeed they have not already been utilized.

There would appear to be no reason why the same principle might not be applied to balloons of the dirigible type, particularly if planes similar to those of the airplane were depended on in part to give the apparatus buoyancy. It may be re-

called that the original dirigible balloon of Santos Dumont was so constructed that it was but slightly less heavy than the atmosphere it displaced, so that it would not rise except when under propulsion. A Zeppelin constructed in compartments could be made to point its nose upward or downward by changing the temperature in its different parts, its ascent or descent being thus facilitated on the principle that was utilized in steering the balloon of Santos Dumont. And of course it could be given greater or less buoyancy as a whole by modifying the temperature of the air, and in this way rendered much more manageable than the hydrogen-filled balloon. A constant source of energy, supplied by gasoline engines or storage batteries, would of course be necessary to maintain the temperature during prolonged flight; but this would be a small disadvantage in comparison with the enormous gain from the use of a non-explosive gas. Perhaps the ideal conditions will be approximated with a balloon having central compartments permanently filled with helium gas and end compartments utilizing heated air of varying temperature. Ultimately helium may be available in adequate quantities to meet all requirements. The density of helium is about twice that of hydrogen, but it not only is non-inflammable but resists all efforts to make it combine with any other element. So the principle of heating the gas to give it still greater buoyancy could be applied to the helium balloon as readily as to the air balloon.

A dirigible of this type might prove a formidable foe for an entire phalanx of airplanes;

whereas the hydrogen-filled dirigible is the easy victim of any airplane that can come near it.

The Zeppelin of the old type was as helpless in the presence of an airplane as a hawk in the presence of a kingbird; but a Zeppelin with a non-inflammable body would be a bird of another color.

From all of which it would appear that the art of balloon-making is only at a transitional stage; and that the next stage of progress will probably be accomplished by taking a leaf from the notebook of the Montgolfiers, away back there in the eighteenth century, and extending with the aid of gasoline engine and storage battery the principle which they borrowed from the blowing of soap bubbles.

Tradition has it that James Watt accomplished his epochal development of the steam engine through watching a tea kettle. If Count Zeppelin had chanced to give thoughtful attention to some youth who was blowing soap bubbles, it is within the possibilities that the World War might have terminated differently. For a non-inflammable Zeppelin in existence at the beginning of the war would have been an instrument of destruction that conceivably might have brought military affairs to an early crisis. So the world at large owes a debt of gratitude to hydrogen, the gas that proved our effective ally.

A NEW ERA IN BALLOONING

The successful flight of the army "blimp" called C-2 from Aberdeen, Maryland, clear across the continent to Los Angeles, calls attention to the fact that the lighter-than-air machine is still

(1922) regarded as an important factor in military preparedness. The fact is further emphasized by the reported preparation of a helium-filled army balloon as a carrier of airplanes. And now comes the report that the great dirigible ZR-1, nearing completion (Mch., 1923) at Lakewood, New Jersey, is being groomed for test flights to the poles and round the world.

When a balloon has been developed that can be depended upon to make a transcontinental or transoceanic voyage, carrying a galaxy of airplanes festooned beneath it like grapes on a vine or perched on top of it, like swallows on a roof, another very significant step will have been taken in the new art of flying that must have a dominating influence in future warfare.

When a flock of bomb-carrying airplanes can be literally carried round the world by an airship, to be sent out as scouts or on destructive missions, and come back at will for refueling, aerial warfare will take on new significance.

Under such conditions, no city will be safe from attack, and the remotest resident of any country that is at war will be in effect on the firing line. There will be no non-combatants.

Nothing quite like that was feasible hitherto, because balloons have been inflated with hydrogen, which is a highly inflammable gas. Such a balloon may be destroyed by any airplane that can get near enough to send an incendiary bullet through it. Moreover, it is always in danger of being exploded by some chance spark from its own engine.

The scientific discovery that augurs a new era

in ballooning was made toward the close of the war. It consisted in the discovery that certain natural gases in this country contain a considerable proportion of the non-inflammable gas helium, which can be isolated at a cost within reason, so that sufficient supplies of it may be obtained to fill large balloons.

Helium, the "sun-element," is so named because it was first discovered in the sun, with the spectroscope. The discovery was made by Sir Norman Lockyer. A good many years later helium was found in small quantities in the earth's atmosphere by Sir William Ramsay. But the total quantity of it isolated until very recently was only a few cubic feet, and the expense of producing it was prohibitive.

The fact that certain gas wells in this country contain helium in relatively large quantity gives our military authorities an advantage of tremendous significance. It can scarcely be doubted that the helium balloon will play a determining part in military affairs of the future.

The thing to be desired, of course, is that the existence of a fleet of helium-inflated airplane carriers with an indefinite radius of operation may be instrumental in preserving peace. But should war unhappily be declared, the same agencies may exert a preponderant influence in bringing hostilities to a quick termination.

A NEW ASPECT OF THE CONSERVATION PROBLEM

The destruction, with the frightful loss of life, of the giant dirigible Roma in 1922 practically illustrated the necessity of substituting helium

gas for hydrogen if the balloon is to become a dependable vehicle of navigation.

It was pointed out by Professor Moore, the government expert, that, whereas before the war the cost of helium was about twelve thousand dollars per cubic foot, the discovery of the gas as a component of various natural gases has led to the development of a method that makes feasible its isolation at a cost of only about ten cents per cubic foot. Under these circumstances, there seems no possible excuse for failure to secure quantities of helium adequate for inflation of all dirigibles utilized by the government. It is suggested that certain gas wells should be set aside as relative permanent reservoirs in which helium may be extracted as needed.

The necessity for this will be obvious when it is stated that, under existing conditions, the gas wells are being exhausted at such a rate that the time may not be distant when no helium-bearing gas may longer be available. To have the helium wasted is a calamity in its way more inexcusable than the destruction of the forests—for helium will not grow again. At all events, the production of helium through the breaking down of the radioactive minerals is so slow that the exhaustion of present supplies will be irremediable for many human generations.

It is within the possibilities that science will find a way of liberating helium atoms from substances not considered radioactive; and that this process may be controlled. In that event, we shall be able to manufacture helium as needed. But while this seems a theoretical possibility, it must be added that no one at present has even an inkling of a

method by which the applied disruption of normally stable atoms may be brought about. The possibility is too remote to serve to palliate in the slightest measure the egregious blunder of wasting the existing supplies of helium.

CHAPTER VIII

WHAT THE AIRPLANE ACCOMPLISHED

IN THE early days of the war, it became evident that dueling of a new type would be in order. It had been found that an observer in an airship, looking directly down upon the water, can often see objects at a considerable depth. So it appeared that the submarine's chief danger would be from aerial craft. These two newest types of fighting mechanisms would thus be pitted against each other.

To attack from such a source the submarine obviously has no response; so there would seem to be no reason why the dirigible balloon or airplane might not fly directly over the submerged vessel, once it is discovered, and drop explosives into the water just above it with destructive effect.

The air craft which may thus be expected in a measure to checkmate the submarine constitute so recent and so spectacular an addition to the fighting equipment of our navies and armies that the history of their introduction is familiar, at least in general terms, to everyone.

It will be recalled that M. Santos Dumont made his spectacular flight about the Eiffel Tower at Paris, which first clearly demonstrated the possibilities of controlling the direction of flight of a balloon, in the year 1901. Almost simultaneously the first successful flights of Count Zeppelin's airships began to be made.

Two years later, in December, 1903, the first

flight in a heavier-than-air machine was made by the Wright brothers at Kittyhawk, North Carolina.

Several years elapsed, however, after the first partially successful trials of the dirigible balloons, before these mechanisms were developed to a stage at which they assumed even relative usefulness. And the airplane of the Wright brothers remained quite unknown to the general public for more than four years after its practicability was demonstrated, during which time the inventors vainly strove to interest the military authorities of their own government, and were only partially successful in attracting the attention of foreign governments, to which they turned after Washington had persistently refused to give their wonderful new war machine a trial.

So the extraordinary and unprecedented development of the dirigible air craft, which has resulted in giving fleets of these vessels to every important military power, has taken place within a very brief term of years.

He would have been regarded as a visionary and foolhardy prophet who had predicted at the beginning of the nineteenth century that in the next great European war flying machines would play a conspicuous part, modifying almost to the point of revolution the tactics of attack and defense. Yet such proved to be the case.

By the time when the great conflict broke out in Europe in the late summer of 1914 each of the chief participants in that conflict was provided with a notable array of dirigible balloons and airplanes; and the latter type of craft in particular had already demonstrated their value as

accessories to the military organization in a number of minor conflicts, notably in the Balkan wars and in Mexico. From the outset, then, companies of airmen were requisitioned at the front, and their scouting capacities gave the tacticians such sweeping vision as had never hitherto been possible, and made it out of the question to hope to move considerable bodies of troops into any territory within a hundred miles or so of the enemy without his full knowledge.

Not only could the airmen discover the movements of the enemy, and thus frustrate any attempts at surprise, but on occasion they gave additional service by dropping smoke-producing bombs directly above the enemy's intrenchments, thus supplying a visible object which could be sighted by the range-finders of their own army.

The airmen performed a service of another kind by flying far into the country of the enemy, and terrorizing the inhabitants by dropping bombs here and there. In the course of these raids, successful attempts were made to drop bombs on the hangars in which balloons of the enemy were housed, and it would appear that various dirigibles were thus put out of commission. A notable instance of this was the flight of three English aeronauts on November 22, 1914, from French territory to the headquarters of the Zeppelins at Friedrichshafen. After dropping bombs, two of the airmen returned safely, the third being brought down, wounded, by the rifle fire of the defenders.

Meantime dirigible balloons had made night forays into the territory of the enemy, dropping

bombs with destructive effect, in particular upon the buildings of Antwerp.

But in general it may be said that the early history of the air craft in the great conflict which first gave opportunity to test their capacities, revealed them as scouting mechanisms, rather than as mechanisms of offensive warfare. The quantity of explosives that an airplane could carry is at best limited, and the accuracy with which these could be discharged from a height was not very great. The dirigible balloon could of course carry a far larger supply of explosives, which could be discharged with greater accuracy, inasmuch as the machine might be headed into the wind and held practically stationary; but the extreme vulnerability of the dirigible greatly restricted its possibilities in this direction.

On the other hand, the small body of the airplane may be plated with metal of sufficient thickness to give a good degree of protection to its occupant against rifle balls fired from below or from either side. And altho the wings of the airplane can not thus be protected, this is a matter of no great consequence, as ordinary bullets may penetrate them in almost indefinite numbers without doing material injury.

The offensive equipment of the airplane included ordinary bombs, to be dropped by hand or through a tube designed to give them direction; bombs with hooks designed to be carried at the end of a cable and swung against the side of a balloon; and sheafs of arrows a few inches in length and weighing about an ounce each. The latter were carried and discharged in packets of one thousand by the French airmen. When dis-

charged from an altitude of two or three thousand feet, they attain enormous velocity, their momentum being sufficient to carry them clear through the body of a horse and rider. No doubt these missiles proved effective on occasion when launched against bodies of men marching or lined up in the trenches; and it was reported in December, 1914, that a German, General Von Meyer, was struck by one of these missiles and instantly killed when descending from his automobile in Belgium.

Guns also were especially designed for use in the airplane. An interesting example of this type of weapon is the rapid-firing Lewis gun invented by an American officer, which is provided with a corrugated aluminum jacket, to minimize heating by facilitating radiation; and which, as was soon demonstrated, could be used effectively from the vantage-ground of an airplane in full flight. In airplanes of the monoplane type the machine gun is mounted in front of the pilot. In the biplane the operator of the gun may sit beside the pilot, or in a seat especially designed for his use under the seat of the pilot, beneath the lower plane. The latter arrangement, as adopted in some English biplanes, seems to give the pivoted machine gun peculiar advantages in directing its missiles against troops of soldiers on the ground or against the deck of a ship.

The chief use of such a weapon, however, was in offensive or defensive conflict with another airman, rather than in attacks directed against forces at the surface of land or water. Nothing developed to give the flying corps real significance in competition with the infantry and artillery

services or the regular naval equipment of the modern military machine, altho their place as invaluable auxiliaries was incontestably established.

It does seem within the possibilities, however, that in future wars a modified type of airplane may come to perform the function of an aerial torpedo; and if this prediction should be verified, our navies will be supplied with a new weapon of quite unexampled destructiveness. Our first concern, however, is not with future possibilities, but with actualities of the recent war.

BOMB-DROPPING AIRPLANES

If wise old King Solomon could have come back to earth and paid a visit to western Europe, say in the summer of 1918, what he saw there would probably have impelled him to disavow one at least of his justly celebrated apothegms. For up there under the sun, sailing along on magic wings, he would have observed a mechanism which candor would impel him to admit as "something new." He might contend with some show of reason that cannon are only modified catapults, and that tanks are modified war-chariots; but for the airplane he could name no man-made prototype. It is a thing of a new order.

But Solomon, after his three thousand years or so of slumber, would view the airplane with no more wonderment than Napoleon Bonaparte who died less than a century ago, or General Grant who lived until 1885; or, let us say, Admiral Sampson, whose death occurred only in 1902. And for that matter, one may admit that the airplane is a perpetual source of wonderment to all of us

even to-day. When you see one of the clumsy mechanisms standing out there in front of its hangar, you are quite disposed to agree that Professor Simon Newcomb was right when he demonstrated that no such heavy apparatus can ever possibly fly. It seems not in the least plausible that a relatively tiny propeller can be whirled in such a way as to lift that giant steel porpoise off the ground. And when the thing actually does defy reason and gravitation and soar up into the sky, and there dive about in such spectacular fashion as to justify Pegoud's scornful assertion that "the birds do not know how to fly," you are quite disposed to admit that you have witnessed a miracle.

But of course this miracle, like all others, is accomplished not by defying all natural laws, but only by defying some of them through the co-operation of others. The flight of an airplane is, in point of fact, far less mysterious than the flight of a bird; it seems more wonderful only because we have not all our lives been accustomed to witness it. Our children's children, accustomed to flying about from the time they are out of the cradle, will marvel that their old-fogy grandparents could ever have seen anything remarkable about so simple and plausible a vehicle.

Meantime, in that year 1918, the airplane was by way of revolutionizing warfare. Not, as the newspaper reader might suppose, because of the exploits of those knights of the air, the fighting pilots,—the Immelmans, Richthofens, Guynemers, Lufberrys, Foncks, and Bishops,—who at best must remain a limited company whose individual deeds of valor are romantic rather than epochal;

but because of the activities of the flying craft of a larger and clumsier type which it was the chief task of the fighting pilots to protect. This all-important mechanism, which made of warfare a new game, is the observing and bomb-dropping airplane. It is a machine that could give a fairly good account of itself in a man-to-man fight as well; but its genuine importance depended on its functions of spying on the enemy—recording his movements, photographing his entourage—directing cannon fire, and on occasion taking an aggressive hand at the war game by dropping sundry tons of bombs where they would be least relished by the enemy.

The general activities of observing and bomb-dropping planes are well understood; but I wish to call attention to some scientific aspects of the feats accomplished by the operators of those machines; and in so doing to point out certain limitations on their efficiency that are imposed by the conditions under which they necessarily operate. In particular I wish to note some of the difficulties that were met in developing the altogether new department of ballistics known as bomb-dropping.

First, however, a few words about the type of observation known as "spotting," that is to say watching the fall of shells from a battery and reporting by wireless just how far they miss the intended target. As the observer is perhaps two miles in the air, watching a target possibly two or three times as distant, it is obvious that a good deal of judgment is required in accurately estimating the distance of the exploding shell from the target.

It will be obvious that in order to make this estimate anything more than a wild guess, the observer must know with a fair degree of accuracy how far away he is from the object he is watching. An experienced observer can of course learn to make helpful guesses with the unaided eye, but apparent distance is so much modified by atmospheric conditions that instrumental aids are essential. The instruments needed are, however, few and extremely simple. The airplane is, of course, provided with an altimeter, which registers the altitude as gaged by varying air pressure. On a given occasion, the observer notes, let us say, that he is at a height of two miles. If the machine is flying on an even keel, the target under observation—which perhaps is an enemy battery—will obviously lie at a downward angle.

An instrument as simple as two cross sticks, one attached vertically to the airplane, the other pivoted, enables the observer to measure this angle.

He finds, let us suppose, that it is an angle of forty-five degrees from the vertical. His line of sight then represents the hypotenuse of a triangle the vertical side of which (represented by his altitude) is two miles, and the horizontal side (along the ground) is also two miles. It is elementary Euclid that the square of the hypotenuse equals the sum of the square of the other two sides; so a very simple computation will show that the line of sight in the present instance is about two and three-quarter miles.

As a matter of course, the observer will not be required to make this computation; it will be read from the index of his instrument. He will know

also that each fifth of an inch marked on the little thread-like scale that is about a foot in front of his eye and is projected so as to seem to lie against the target, represents a stretch of one hundred yards at a distance of two and three-quarter miles.

Thus he is able instantly to measure the distance from the target of the exploding shell. The direction from the target is conveniently recorded in terms of the figures on the face of a clock. The shell has perhaps fallen somewhat short and to the right, say three-fifths of an inch away, as the observer sees it. At once he radios: "Three hundred yards toward four o'clock," or some shorthand equivalent, and the gunner knows how to correct his aim.

When the airman is required to take a direct hand in the destructive game by dropping bombs, his task might seem a very simple one. Bombs will obviously reach the earth from whatever height they are dropped; and the higher the altitude, the greater the force of impact. So what more is necessary than for the airman to soar out of range of enemy anti-aircraft guns, get directly above the object he wishes to destroy, and touch the button that liberates the missiles?

Unfortunately or fortunately—according to whether you are viewing the matter from your own standpoint or that of the enemy—a great deal more is necessary. Were the airman to essay his bomb-dropping expedition on such a basis, no place could be safer than the munitions factory, ammunition dump, or fortification that he intends to demolish. *Nothing is ever hit by a bomb dropped from an airplane directly above it.*

The only way an airman at any considerable height can hit a given object is by dropping his bomb while the object is still far ahead of him.

The explanation of this paradox is that a bomb carried by the aircraft necessarily partakes of the forward motion of the machine, and, in accordance with a simple law of mechanics, retains that forward motion after it is liberated. If the airplane continues its flight at unmodified speed, it will continue directly above the bomb in all stages of the latter's fall. In other words, the bomb will keep steadily abreast of the airship, except for a slight modification due to air resistance, and will ultimately strike the earth and explode directly beneath the craft that dropped it, tho the latter may be three or four miles in the air. If at the moment when the bomb explodes the aircraft were to release another missile, this second bomb would duplicate the parabolic course of the first and ultimately explode perhaps a mile or two farther on, the exact distance depending of course upon the speed and height of the airplane.

All this simply illustrates the same principle that is illustrated when you throw a ball vertically into the air and it drops back straight into your hands. While the ball was in the air, you, standing on the earth surface, have been swept along through space (at the rate of a thousand feet or so per second) as the earth rotates; but the ball has partaken of this motion; and to you it seems to have gone straight up and straight down, altho its actual course was something quite different from this. If objects thrown from the earth did not thus continue to partake of the earth's motion,

they would be swept off into space never to return. This, indeed, was one of the arguments advanced against the theory of the earth's motion, when Galileo put forward that thesis and made his celebrated demonstration at the Leaning Tower of Pisa.

The simple laws of motion the discussion of which provoked such a hubbub in Galileo's time are perfectly well understood to-day; and the bomb-dropping airman must bear them in mind and govern himself accordingly.

It is true that the fighting pilot, in his swift, light machine, may on occasion swoop down like a swallow and project a bomb as a catapult; or may release a small projectile while performing a spectacular loop-the-loop that finds him momentarily stationary in the air. But the regular bomb-dropping machine, with its tons of missiles, must carry out its task in more prosaic fashion. It must ordinarily fly at an altitude well above the range of anti-aircraft guns, and must either drop its missiles at random, in which case they will usually hit nothing in particular but the landscape; or else must utilize the same type of skill and calculation used in the direction of explosives that are thrown from cannon.

The force of gravitation, which opposes the gunner, aids the bomb-dropper. After the cannon ball has reached its full height, however, its status is exactly that of the bomb just released from an airplane; both missiles proceed to their ultimate destination in a parabolic curve modified somewhat by air resistance.

The gunner determines the vertical line of flight of his missile by aiming his cannon. He must

sight the object he intends to bomb—away off ahead and far below—and move directly toward it. To accomplish this, he must have an apparatus equivalent to the sights of the cannon, and the object must lie directly in the line of his sights when the bomb is released if the shot is to be effective.

Granted, however, that the airman has sighted perfectly and that his airplane is moving precisely in the right direction, how is he to know then to release the bomb so that it will be pulled down by gravitation along just the right course ultimately to find its mark?

This, obviously is a puzzle. Yet it is a puzzle comparatively easy of solution provided the airplane is moving on an even keel at a known altitude and at a known speed. The airman is then called upon to deal with a simple problem in triangulation, in which, as in the case of the "spotter" above referred to, the implements required are essentially a fixed vertical bar and a pivoting crossbar that may be aimed at the object to be bombed.

It is only necessary to recall that the bomb, once it is released, will go forward at the same rate of speed with the airplane (with slight allowance for air resistance); and secondly, to recall that gravitation will bring the bomb to the earth in a given time from a given height, to make it clear that the bomb must be released at such a point that the number of seconds required for its fall is the number that the airplane will require to bring it directly above the object to be bombed. Both these factors are readily calculable when the height and speed of the airplane are known.

Suppose, for example, that the airplane is two miles high and traveling at a rate of one hundred and twenty miles an hour. A body dropped from this height will require a little more than thirty-five seconds to come to earth. In thirty-five seconds an airplane going one hundred and twenty miles an hour covers about one and one-sixth miles. Therefore the bomb must be released when the target is one and one-sixth miles ahead. Here, then, we have another simple problem in geometry, dealing with a triangle of which the vertical (the height of the airplane) is two miles and the horizontal (earth line) one and one-sixth miles, from which it may readily be calculated that the angle where the hypotenuse cuts the vertical (at the point of which the observer's eye rests) is an angle of about thirty degrees. Nothing is practically required but to fix the pivotal bar at this angle and sight along it as the airplane moves forward until the sight touches the target. At that instant, touch the button releasing the bomb—and let gravitation do the rest.

In the first second after it is released the bomb will move forward about one hundred and seventy-six feet, while falling only sixteen feet; by the tenth second its downward flight will about equal its forward flight; by the twenty-second second, it will be falling twice as fast as it moves forward; and in the thirty-fifth second, just before it strikes the ground, it will shoot downward about five hundred and forty feet, whereas the original forward movement of one hundred and seventy-six feet will be somewhat retarded by the atmosphere; so that the final impact of the bomb will be almost vertical.

All this is simple enough in theory but we must recall that in practise the factors are nearly all somewhat variable. It can not be known precisely how high the airplane is nor precisely how fast it is moving. Nor will the machine move exactly on an even keel. Nor can it be aimed at the target with absolute accuracy. Yet it must be recalled that if the machine swerves so much that the line of the fall of the bomb varies by one foot from the true course in its first ten feet of fall, it will altogether miss a target a half mile in diameter. Even if the deviation is but a single inch the missile will fall outside a target one hundred and eighty feet in diameter.

Again, if through miscalculation the bomb shall be released a few seconds too soon or too late it will fall short of the target or overshoot it by one hundred and seventy-six feet for each second of the miscalculation. And now the airman is at a great disadvantage as compared with the gunner, since he can not correct his aim from observation of his mistake and try again. Each of his shots is a fresh experiment. His only resource is to release a series of bombs in rapid sequence, beginning just before his sight reaches the target and continuing for a few seconds afterward.

The alternative would seem to be to fly low and take a chance against the anti-aircraft guns with their incendiary missiles—"flaming sausages" and what not—which is a hazardous procedure even at night; or to find some means of checking the forward flight of the bomb so that it could be dropped from directly above the object it is intended to strike. There are various ways in which this might be accomplished; for example, by use

of a catapult that would throw the bomb backward at a speed precisely equivalent to the forward movement of the airplane. In effect the bomb would then become stationary in air for an instant, and drop vertically. It is by no means certain, however, that the airman, from his swiftly moving coign of vantage, could determine the vertical with such precision as to drop the bomb any more accurately than by the method above described.

As to these and sundry other features of the new science and art of bomb-dropping, we shall have fuller information when experience has taught its lesson. At present, the art of bomb-dropping may be said to be about at the stage of cannon shooting in the days of the smooth-bore weapon without sights. Of the thousands of tons of explosives that have been dropped from airplanes during the war, doubtless by far the greater part exhausted its vicious explosive energy on earth and air alone. But more and more effective hits were made as the war proceeded, and the prospect of having thunderbolts hurtle about one's head from inaccessible cloudland proved prodigiously exasperating to the old-fashioned infantryman, earth-bound, unprotected, and denied even the privilege of retaliation.

SINKING WARSHIPS

It should constantly be borne in mind that the airplane was a new device, and bomb-dropping an utterly novel procedure. Even at the close of the war, less than ten years had elapsed since Orville Wright made his official demonstration that a heavier-than-air machine can carry two

passengers and fly five miles across country and return. It was only during the war itself that the possibility of making airplanes capable of carrying bombs of a ton weight or more was demonstrated. And the war closed just too soon for a demonstration of what far-flying weight-carriers might accomplish in the way, for example, of sinking ships.

So the question as to whether this new instrument of warfare was to be accorded position as a really formidable enemy of the battleship was regarded by many as an open one. The question was settled decisively, however, in the summer of 1921, when official tests were made in which sundry antiquated ships of the American navy and various German prize ships that had been turned over to us were used as targets for bombs of various types and sizes dropped from airplanes.

Preliminary tests were, indeed, made somewhat earlier, for in October, 1920, Navy seaplanes dropped bombs on the old battleship *Indiana* in Chesapeake Bay; and shortly thereafter Army bombers were permitted to experiment in the same way with the *San Marcos,* formerly the *Texas,* a once-famous battleship.

These tests, however, were carried out under conditions that rendered them indecisive. It was declared in a report to the Secretary of the Navy that the experiment with the *Indiana* "pointed to the improbability of a modern battleship being either destroyed or completely put out of action by aerial bombs."

But the results were quite different when the carefully trained aviators were permitted again to go into action the following summer. They began

on June 1st by sinking the German submarine U-117 in sixteen minutes; followed on June 29th by finding the old battleship *Iowa* as she was cruising under radio control in a 25,000-mile-square area and attacking her with dummy bombs; continued by sinking the light cruiser *Frankfurt* within thirty-five minutes after opening the main attack with Army Martin bombers; and concluded with a spectacular demonstration in which the German dreadnaught *Ostfriedland,* a modern ship of 22,800 tons that had taken a prominent part in the battle of Jutland, served as target.

On July 20, 1921, the *Ostfriesland* was attacked with small bombs only—that is to say, with bombs of from 230 to 600 pounds, the attacking planes being five Marine DeHavilands, four Army Martin bombers, and eleven Navy F-5-L's, flying at heights of from 1,000 to 1,600 feet.

Of ten direct hits, nine bombs failed to explode. Some shots striking near the target were spectacular, causing immense sheets of flame to envelop parts of the ship. But after the fifty-three bombs had been dropped, the fighting parts of the dreadnaught were still intact; and night closed on what the opponents of the aircraft regarded as substantially a failure.

But the airmen were by no means disheartened. They had been attacking "a floating fortress, with heavy steel walls built to withstand the mightiest gun projectiles," and had been restricted to the use of weapons relatively of the popgun order. On the morrow, things were to be different.

And different they certainly were. At the outset it was discovered that some of the seams of the vessel had been opened by the bombing of

the preceding day, and that the ship had settled two feet by the stern overnight. That made it evident that the attack of light missiles had been by no means ineffective. When bombs of 1,000 pounds were now substituted three direct hits were made, and at each impact the great ship quivered and pitched under the shock.

Then came the final phase, when seven Army bombers each carrying a single 2,000-pound bomb were sent against the dreadnaught, at the prescribed height of 2,000 to 2,500 feet. General Mitchell, who commanded in person, was convinced that direct hits were not desirable, correctly supposing, on the basis of earlier experience, that shots placed in the water near the vessel would have even greater effectiveness. So four bombs were purposely dropped in the water close to the dreadnaught. A fifth exploded on the deck, and another fell 300 feet in advance. It is reported that the shocks were distinctly felt on the observation ship *Henderson*, three miles away.

The stricken warship "pitched, was deluged with tons of water, and almost immediately began to sink by the stern. Her bow rolled out of the sea, she rolled over and, twenty-one and a half minutes after the first 2,000-pound bomb was dropped, she took her final plunge. It was a sight to thrill; and sportsmanship in both services sent forth cheers and applause to the fliers, as the seventh bomber, arriving just as the ship went down, dropped its T.N.T. into the foaming, eddying vortex."

I quote this description of the final scene from the *Aircraft Year Book* for 1922. Extended comment is hardly called for. It suffices to note that,

sequential to this achievement, a Conference on the Limitation of Armaments was called in Washington, and that by international agreement the battleships of the United States and of England, France, Italy, and Japan were limited in number (eighty-six capital ships built or building at the moment to be scrapped); that the United States and Great Britain are to limit themselves to the building of five airplane-carriers each, France and Japan being limited to three each, and Italy to two; but that it was not considered feasible to put any limitation upon the development of aircraft of any type.

When General Williams, Army Chief of Ordnance, witnessing the sinking of the *Ostfriesland* from the observation ship, said: "A bomb was fired to-day that will be heard around the world," he made no mere rhetorical flourish. It was a detonation even more far-reaching than the words literally imply. It resounded even in the secluded chambers of the Capitol at Washington.

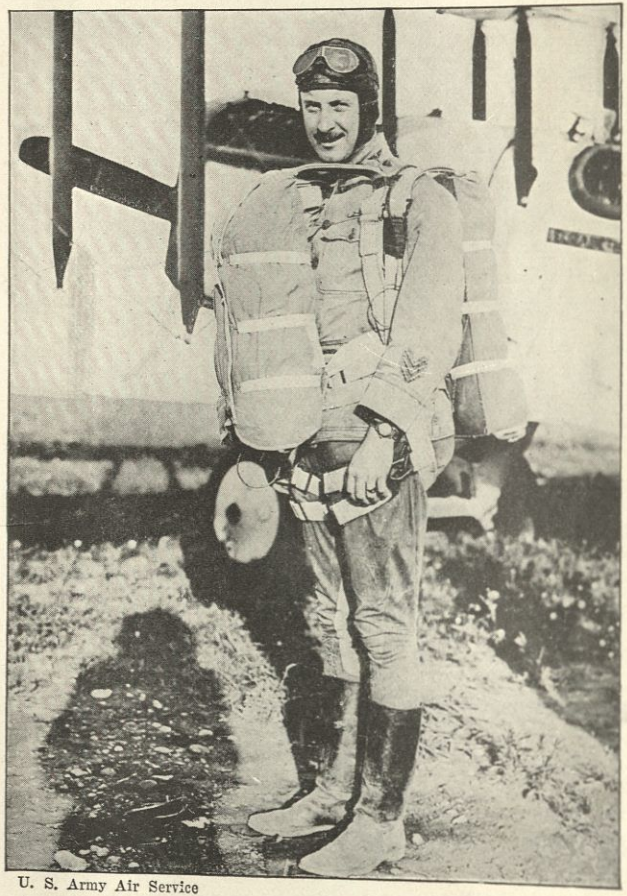
CHAPTER IX

GRAPPLING WITH DISEASE

IT IS pretty generally understood that bullets are by no means the most dangerous enemies of an army. The records show that in most wars during the past century only about one man in fifty died from gunshot wounds. Yet the total number of deaths reached the proportion of one in ten, on an average. Obviously, then, there is some enemy of the soldier at least four times more dangerous than his human antagonists. And any veteran, even of a single campaign, understands that his enemy—one that has decided many important campaigns in history—is disease.

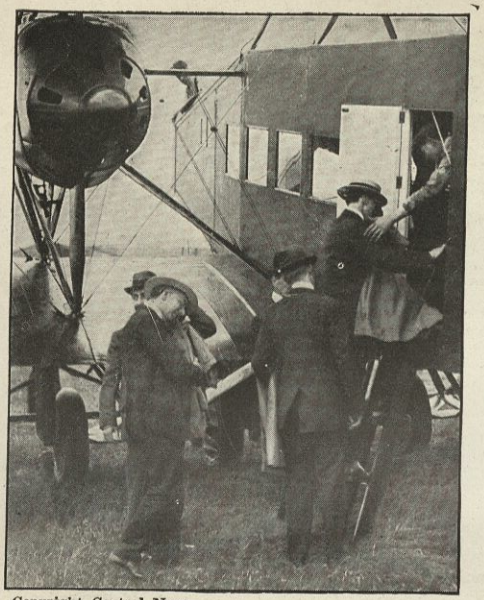
Yet, paradoxical as it may seem to those unfamiliar with the difficulties of a campaign, the maladies responsible for the greatest number of deaths among soldiers are those known to physicians as "preventable" diseases.

Even if all these things were generally known, it is probable that in the excitement of impending war there would be the same rush of patriotic volunteers to join the colors against an enemy. Yet there would be a natural revulsion on the part of the soldier in feeling that his chances of dying ingloriously in a hospital of some loathsome disease instead of on the battlefield were fully four to one. He would not choose such a death of his own volition. It is unjust, but nevertheless true, that the simple epitaph, "Died while defending his country," conveys the meaning of



U. S. Army Air Service

AVIATOR PREPARED FOR EMERGENCIES



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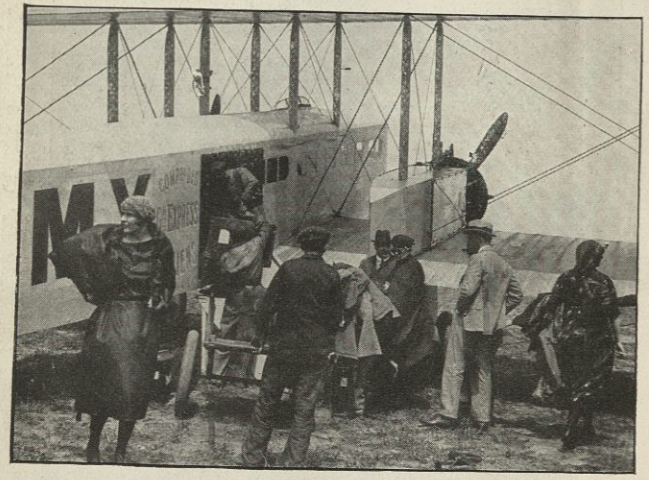
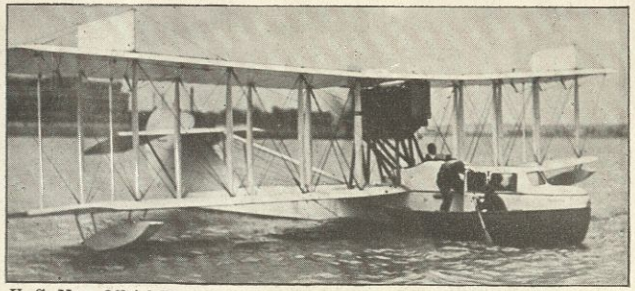
EUROPEAN PASSENGER PLANES WITH SIDE ENTRANCE (LEFT) AND FRONT ENTRANCE. MACHINE AT RIGHT CARRIES EIGHTEEN PASSENGERS

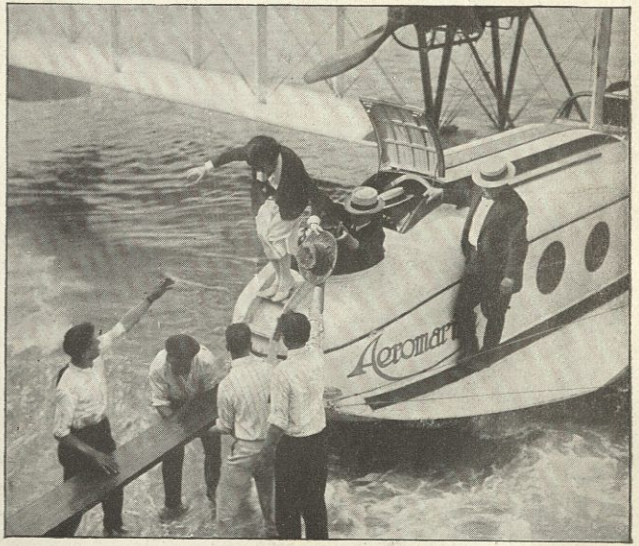
INTERIOR OF CURTISS "EAGLE" PASSENGER PLANE



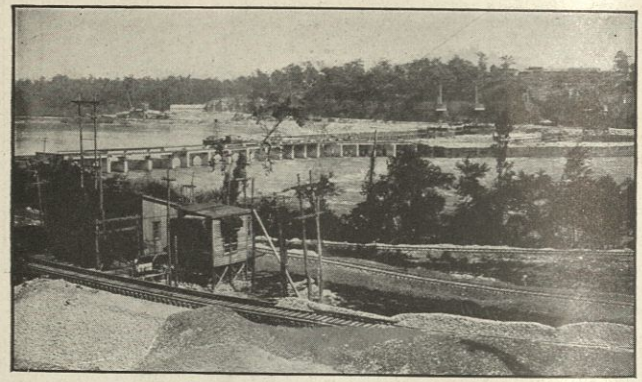
"ALL ABOARD" AT COMMERCIAL AIRPLANE STATIONS NEAR PARIS (BELOW) AND BERLIN

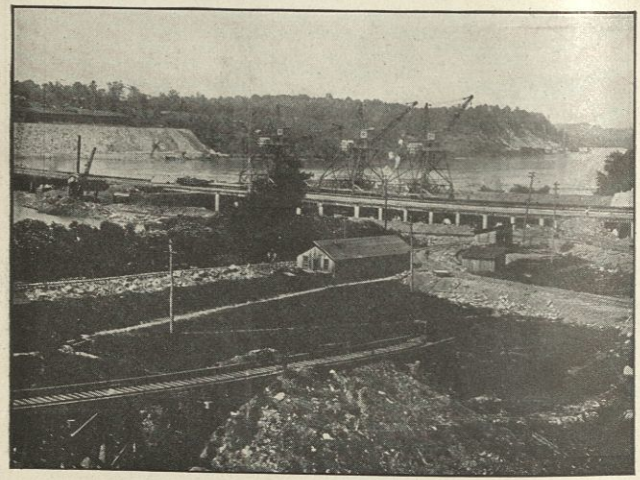


U. S. Navy Official Photo

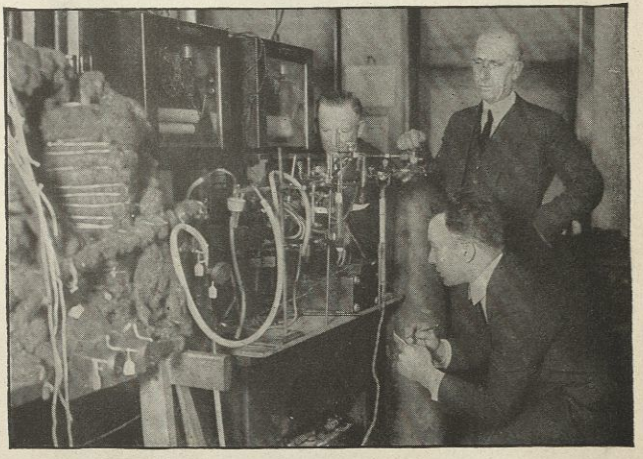


COMMERCIAL FLYING BOAT SERVICE BETWEEN NEW YORK AND ATLANTIC CITY (BELOW), AND AERO-MARINE FIVE-PASSENGER FLYING BOAT

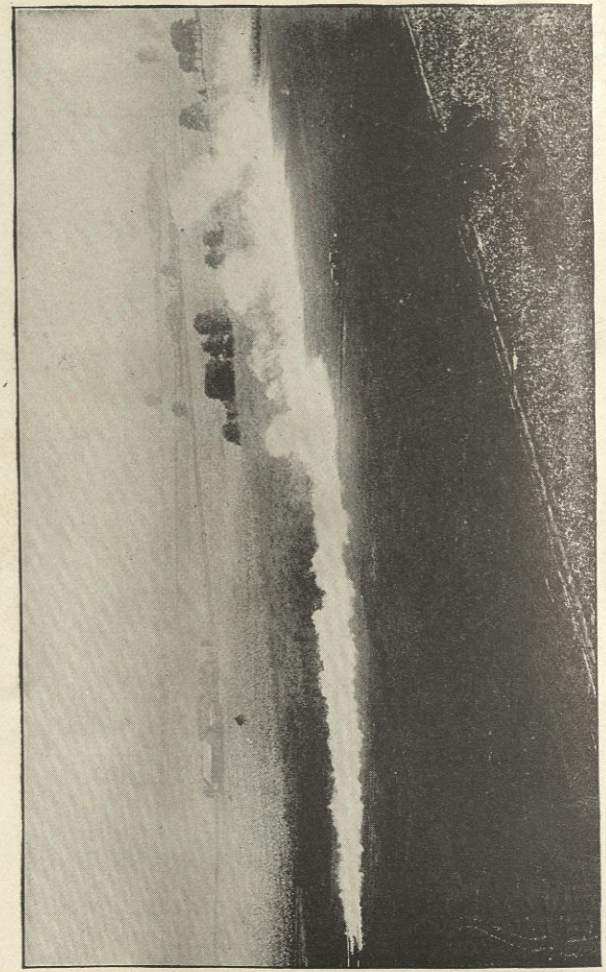




TWO VIEWS OF WILSON DAM AT PROJECTED NITRATE PLANT AT MUSCLE SHOALS



BUREAU OF MINES EXPERTS DOING RESEARCH WORK ON HELIUM GAS TO BE USED FOR INFLATION OF DIRIGIBLE BALLOONS



SPRAYING ORCHARDS WITH INSECTICIDE FROM AN AIRPLANE

a much more glorious death when there is added "in battle," instead of "of disease." And the time is at hand when, knowing as we do now the cause of most diseases and the simple methods of preventing them, the soldier and his friends who remain behind will not observe with equanimity or tolerate the record of disease ravage that has made war more than doubly terrible in the past.

Disease has been the deciding factor in many of the great campaigns in history, whether those of a Pharaoh in Egypt, a Hannibal, or a Napoleon. It will be recalled that the army of the Assyrian, when he "came down like a wolf on the fold," was stricken by the "angel of God" and decimated: in short, his army was so afflicted by disease that he was obliged to raise the siege for want of fighting men. And succeeding centuries have witnessed similar disasters.

In modern times cases are recorded where regiments were exterminated before they could reach the seat of war. This is said, on good authority, to have happened in the Crimean War, when in one campaign of six months it is estimated that, in a loss of fifty thousand men, only two thousand died from bullets.

Even more shocking than this record is that of the French in the Madagascar campign of 1894, where, out of fourteen thousand men in the field, seven thousand died of disease, while only twenty-nine were killed in battle.

In the Civil War a little less than the proportion of four to one died from disease, as against those killed in battle; while in the Franco-Prussian War the Germans, probably for the first time in the history of warfare, made the remark-

able record of having fewer, by half, die from disease than by bullets. Meanwhile the French were being weakened day by day by the ravages of the archenemy.

When the Spanish-American War broke out, our own progressive country was so ill prepared with modern equipment for combating disease that at the end of a hundred days—about six weeks of actual fighting—some three hundred men had been killed, and about four thousand had died of disease, or a proportion of about fourteen to one. The West had not profited by experience.

Then came the Russo-Japanese War, in which the Oriental armies lost but one man from disease to every four killed on the firing line—an absolutely unprecedented record.

And yet all that Japan knew of the methods of preventing disease she had learned from Western nations. She made no discoveries of new things or methods that were not the common knowledge of every physician, and of thousands of laymen. She simply put into practise what the West had taught her.

From this record of the Japanese army it will be seen that the so-called "preventable" diseases are really preventable: that the medical man was not dreaming the dreams of the visionary when he asserted that most cases of malaria, dysentery, smallpox, and above all, typhoid—the bane of every army—could be prevented even in large armies.

There are, to be sure, a good many diseases that can not be prevented, any more than can such cases in civil life; but about eighty per cent. of all diseases that affect the modern army are

among those mentioned and properly classed as preventable ones.

The two great causes of sickness in an army, aside from wounds, are improper diet and infection by disease germs. Frequently the first of these makes it possible for the other to gain a foothold, so that the improperly fed man is not only subject to diseases that are the direct outcome of his improper diet, but is also rendered susceptible to the disease germ. But so long as there was no means of supplying armies and navies with proper forms of nourishment, as was the case until recent times, these things were inevitable.

Thus before the days of canned goods, when the preservation of perishables was not well understood, it was a foregone conclusion that cases of scurvy would develop among the members of the crews of ships making long voyages. But since it has become known that this disease is caused solely by defects of diet, and now that vegetables of every description can be kept in a canned state indefinitely, scurvy has become a rare disease.

A more striking example of what may be accomplished by proper diet is that of the stamping out of beriberi in the Japanese navy. For a long time the Japanese scientists had been convinced that this disease in their armies and navies was due to the large quantities of rice eaten by the men, to the exclusion of other forms of food. They based their beliefs on observation as well as on well-established physiological facts. They observed, for example, that no cases of beriberi developed among the crews of foreign vessels stationed for years in Oriental waters, and the only

perceptible difference in the treatment of these crews from those on their own boats was in the matter of diet.

It was subsequently discovered that beriberi results from the absence of a substance now known as vitamin, which is found in the husk of the rice, and which is removed with the husk when the rice is polished. It was not the rice diet, but the use of rice "improved" by polishing, that was responsible for the disease.

The very life of the Japanese nation seemed to depend upon the efficiency of its navy; and yet, in 1882, when there was a war cloud hanging over the Far East and Japan seemed likely to be drawn into a struggle with Korea, five of the Mikado's largest war vessels were all but useless, owing to the fact that such a large percentage of their crews were sick with beriberi.

At this time the Deputy Medical Inspector General of the navy was Doctor Takaki—the "Jenner" of the Japanese world. He had studied the subject of beriberi carefully and had reached some very definite conclusions as to its cause, but as yet had had no way of thoroughly testing his theories. But his chance came in 1883, after a protracted cruise of the warship *Ryujo,* lasting two hundred and seventy-one days, during which over a hundred cases of the disease developed among a crew of three hundred and fifty persons.

When the facts of this voyage became known, Dr. Takaki asked the Minister of Marine that another similar vessel be sent over the same course at the same time of year, the regulation ration of the crew being changed to one selected by Takaki. Fully alive to the importance of stamping out the

disease, and having great confidence in his medical officer, the Minister consented, and the *Taukuba* was detailed to make the voyage.

Starting at the corresponding time of the year, and making the same stops and in practically the same time as the *Ryujo,* the *Taukuba* completed the voyage without any serious cases of the disease developing, sixteen mild cases, all told, being reported, as against one hundred and sixty cases the year before on the *Ryujo.*

This was a demonstration that admitted of no appeal as to the cause of the disease that had scourged the Orient for so long. A new dietary was adopted at once in the navy, cases of beriberi became more and more rare, until, by 1887, the disease had disappeared, despite the constant increase in the number of men in the fighting force.

During the Russo-Japanese War the full complement of able-bodied fighting men was kept practically at one hundred per cent., so far as this disease was concerned.

In view of these demonstrations one would naturally suppose that the progressive Japanese army, the peer of any army in the world, and conspicuous for its readiness to adopt useful innovations, would have followed the lead of the navy and changed the diet so as to wipe out this disease. But in point of fact beriberi was the cause of almost one-half of the cases of sickness in the army during the Russo-Japanese War. The army had adhered to the old diet, despite the conclusive demonstration in the navy, and altho a tardy change in the ration was made towards the close of the war, the change came too late to save the one stain that can never be erased from the other-

wise clean and unparalleled record of the army surgeons of the Mikado.

But scurvy and beriberi, the results of improper diet, are about the only diseases known to be directly traceable to the continued use of improper food. There are others, however, such as the numerous germ-produced intestinal troubles, that are indirectly induced by the foods themselves, the germ finding easy entrance to a system improperly fed.

In Western nations, where scurvy has disappeared, and where beriberi does not exist, these are the diseases accountable for the high mortality of the armies.

As every one knows, the so-called germs are microscopic plants which, when taken into the system under proper conditions, multiply and produce diseases. The two great avenues of entrance are the respiratory and digestive tracts. There is also the important source, the skin, through which the disease germs may enter the system either through abrasions or by the action of certain insects, such as flies, mosquitoes, and body lice. If the soldier can escape contamination from these few sources he incurs relatively little danger of being sick on the campaign.

Like all other forms of vegetable life, germs are killed or rendered inert by heating to the boiling point for a few moments; and they succumb to certain chemicals known as "antiseptics." The simple process of cooking or boiling, therefore, suffices to guard against the action of disease germs found in water or in food. Cholera, typhoid, and dysentery may thus be prevented, typhoid being the most fatal of these to modern

armies, and its germ the one with which drinking water is most likely to be contaminated.

The wells along the line of march of the ordinary army are responsible for more deaths than the enemy's bullets. Yet theoretically this should not be so if the soldier is aware that the wells may be germ-poisoned, or that he can purify their water by boiling it. And in practise the Japanese showed that this theory is correct. The record of four men killed to every one that died of disease in the Russo-Japanese War evidences what the scientist in the laboratory has done to ameliorate the condition of the fighting soldier.

Equipped with this knowledge of the cause and means of prevention of the diseases most common to troops in the field, it would seem that every modern army should be able to eliminate the great factor of sickness in the ranks and keep a far higher percentage of men fit for the firing line all through the campaign. But Japan was the first country that succeeded in putting into practise what had been known theoretically for a considerable time. The United States did not do so in her war with Spain; England failed almost as signally in the later war with the Boers; and Russia was probably even less fortunate in her last war, while her opponents were astonishing the world.

England, America, and Russia all knew as much about scientific hygiene as Japan—had, indeed, taught her all she knew of the subject. Why, then, this failure on their part? The answer is simply that they did not get around to do what they were fully aware should be done. Perhaps if they had known that a war was inevitable, and

had known it for ten years, as Japan knew in the case of the approaching war with Russia, other nations would have duplicated her remarkable record in the Far East.

Be that as it may, Japan, seeing the inevitable war cloud looming larger and blacker, laid her plans to carry on a strictly scientific campaign. First of all she showed her faith in her medical men by arming them with authority; and then, after instructing her men to obey them implicitly, she explained to the men in a simple but convincing manner the reason for this obedience. She told them why they should not drink at every well and pool of water; why they should cook certain foods and should avoid others altogether; and what they should do in a general way to avoid all manner of diseases. The remarkable thing is, not that the men believed what they were told, but that they obeyed. The little books of instructions issued to the soldiers contain some simple facts and suggestions that could be read profitably by any person, soldier or civilian, in any walk of life.

"Infectious diseases are caused by the poison getting into the body from the outside, which can be prevented by proper care," says this little book. "These diseases are caused by microscopical objects called germs. In former times the number of deaths from these diseases exceeded the number of those killed in battle. Therefore, never neglect to exercise the utmost caution against these germs.

"The infectious disease that is almost always present with an army is typhoid fever. This is caused from germs in food or drink. Therefore

the first step in preventing it is not to eat raw things and not to drink unboiled water.

"The means of preventing dysentery and cholera are almost the same as those for preventing typhoid fever. Unripened fruit is apt to produce diarrhea, therefore be very careful of that.

"Plague generally comes through injuries to the skin. Therefore even a little wound should be examined by a physician. Never walk with bare feet, as rats and fleas spread this disease: kill them or drive them away.

"Malaria is spread by mosquitoes, therefore protect yourself from them as much as possible."

There were also instructions and hints as to keeping the body in the best possible condition to resist disease. Bathing was especially enjoined; and when this was found impossible at frequent intervals, the men were instructed to rub every part of the body with a dry towel at least once a day. They were instructed to keep the hair cut short and wash the head frequently, and great emphasis was laid on the importance of keeping the hands and feet in the best possible condition, care of the finger nails being especially enjoined. In the matter of dress, elaborate instructions were given, including the care of clothing and shoes, and reasons that would appeal to the soldier were given for all these things.

For example, the saying of a famous commander was quoted, to the effect that the key to the success of an army lies in the condition of the feet.

The soldiers were instructed never to expose the head to the direct sunshine, and never to sleep on damp ground if it was possible to get branches

or straw to cover it. They were warned against drinking too frequently or too freely on the march, and were given such useful hints as that of holding a plum or a straw or leaf in the mouth when no water was available. In a word, they were instructed in the common-sense rules of hygiene which science has evolved. All this was a direct help to the soldier, and so indirectly an aid to the medical officer. In return these officers used every effort to make it possible for the men to carry out the instructions.

One of the most radical innovations introduced by the Japanese was the placing of medical officers in the van of the army.

The place for the surgeons since time immemorial has been at the rear. But the modern idea of prevention rather than cure has been making its way in the armies as well as among bodies of civilians, and the surgeon has gradually found his way to the front of the army, except at the actual time of the engagement. The Japanese used a cloud of doctors for "skirmishers," just as they did the cloud of fighting men—skirmisher doctors who examined wells and streams in advance of the troops, and who set up signs regarding the potability of the water in each. Every scouting or foraging detachment was accompanied by a medical officer equipped with a water-testing outfit. This was carried in a canvas case and contained the proper chemicals for making rough but conclusive tests.

The drinking places were labeled in three ways, according to the result of the tests: "Pure drinking water"; "Filter and boil before drinking"; "Use for washing only; not drinking." And the

mandates of these signs were rigorously followed by the soldiers.

As an adjunct to the corps of field testers were corps of microscopists—"the most deadly foe to the Russian cause," as some one has said, since it deprived them of the aid of disease, that heretofore had been the greatest aid to an opposing force. These microscopists could not accompany the hurrying bodies of scouts and skirmishers, as in the case of the chemical testers; but they could follow more slowly, making exhaustive confirmatory tests, and so clinching the work of their predecessors in the field. It was the duty of these physicians to attend to the improvement of the sanitary conditions of a town where a halt was made for more than twenty-four hours, and their word was law. The sanitary squad in such cases made a careful inspection of every building in the town, ordering those cleaned that proved to be in reasonably good condition, and destroying those that were near the danger line of possible infection.

The result was that, instead of the towns occupied by the advancing armies becoming filthy, infectious disease breeders, as had been the rule with invading armies heretofore, the towns occupied by the Japanese became clean and sanitary —most of them for the first time in their histories.

Cleaning alone did not suffice to protect the troops from possible sources of infection. Foods sold by natives had to pass a rigorous examination by the medical staff, and if condemned were destroyed. There were also rules laid down for regulating the manner in which certain perishable articles should be offered for sale, such as the rule

that all articles offered publicly must be protected from flies. Indeed, the war waged by the surgeons against flies and mosquitoes was quite as persistent and relentless as that against the germs. Specially constructed fly traps were put in use everywhere; and mosquito netting and other means of keeping off these malaria-bearers were used as never before in the history of warfare. All these preventive measures helped to hold the dreaded diseases in check.

THE TRIUMPH OF MODERN SURGERY

The triumph of sanitary science seems the more complete because so very generally unexpected.

In point of fact it was no more remarkable than the other analogous triumph of science, the saving of life among the wounded. But the world has become accustomed to expect the miraculous in surgery, or anything pertaining to the art; so that there was less surprize at the record made by the Japanese of losing only one and one-half per cent. of their army from gunshot wounds, altho twenty-four per cent. were wounded.

The scientific knowledge responsible for this remarkable record is, of course, the same as that which governs the sanitary department—the knowledge that germs are largely the cause of diseases, whether they be in the form of infectious maladies or infected wounds. In either case, the underlying principle of combating them is the same, the principle of prevention. And this prevention consists essentially in keeping the germ out of the wound. The dressing of the wound and subsequent operations, when necessary, may be de-

ferred almost indefinitely if the poisonous germ can be excluded from the fresh wound.

Here again the intelligent aid of the fighting man was requisitioned by the surgeon. Every man was instructed in the causes of diseases in wounds just as in the case of the matter of sanitary precautions. He was also instructed as to what he should do in case he was wounded, and was furnished with a "first aid" package with which to carry out these instructions.

First of all, he was to see that his body was clean before going into battle, and if possible to put on clean clothing so as to lessen the danger of infection from unclean shreds coming in contact with wounds.

If struck by a bullet, he was to tear open his first-aid package at once, apply the dressing and bandage as he had been instructed to do, and either make his way to the rear or wait for the stretcher men to find him and carry him to the hospital in the rear of the firing line.

Had the men been ignorant of the proper method of caring for their wounds, or had they followed the custom of soldiers of a quarter of a century earlier of leaving the wounds alone, or of dressing them with strips of germ-laden clothing, handkerchiefs, etc., the mortality from wounds would have been much the same as in previous wars, and the work of the surgeons greatly increased.

As it was, the surgeons found themselves free to concentrate their efforts in caring for the desperate cases, knowing that the "first-aid" dressings on the minor injuries would suffice for the time being. Indeed, it happened in thousands of cases

that these dressings were not disturbed by the surgeons after the men had applied them, the healing process taking place quite as readily as if the dressing had been applied by the most skillful surgeon.

APPLYING THE NEW KNOWLEDGE IN THE WORLD WAR

Such, then, were the lessons available for the medical authorities of Europe and America when the "World War" broke out in 1914. There was also available a new weapon to combat the deadly pest, typhoid fever; this being the vaccine inoculation devised by Sir Almroth A. Wright, and by him tested in the South African war, of which more will be said in a moment.

Let us now pass in brief review statistics that tell how well the physicians of our day profited by the new knowledge, to the advantage of the fighting hosts in Europe in 1914–1918. It will suffice, for the present purpose, to confine attention to our own troops. It will be of interest, however, to extend the inquiry to include certain matters of vital concern regarding the physical status of our soldiers, irrespective of disease.

At the outset, there appeared this anomaly:

When the earlier reports from the army examining boards began to come in, it was noted with surprize that men drafted from the cities made a better physical showing, on the average, than those drafted from the country. A partial explanation was found in the suggestion that the more vigorous country-bred boys tend to go into the cities.

Then came a report showing that the young

men from the cities in the army camps showed on the average a greater resistance to infections than their country cousins. They were, for example, relatively immune to influenza, the scourge that, with its sequel pneumonia, added so alarmingly to the death rate. The statistics appear to show that rural camps had at least 25 per cent. more cases of influenza, 10 per cent. more pneumonia, 10 per cent. more deaths, and 30 per cent. higher admission rate for all sickness than corresponding urban camps. It appears that the proverbial health-giving character of country life is more or less mythical.

The explanation regarded as most plausible is that any communicable disease tends to leave the body with heightened resistance against all other communicable diseases. It does not follow, however, that the city is a safer residence place than the country during an epidemic; for of course the opportunities for infection are greater in the city. It is consoling, however, to know that the increased danger of infection is at least in a measure offset by the greater average resistance of the city dweller.

KILLING THE DEATH RATE

No feature of the war is more novel or more startling than the one revealed by the statistics of total deaths from disease in the U. S. Army during the war.

It appears that from September 1, 1917, to May 2, 1919, during which time the average strength of the arm was approximately 2,121,000 men, the total deaths from typhoid fever were 213; from malaria, 13; from dysentery, 42; from smallpox,

5. A comparison has been made between this death roll and the number of deaths that would have occurred if the Civil War death rate had obtained, as follows: typhoid fever, 51,133; malaria, 13,051; dysentery, 63,898; smallpox, 9,536. This list totals 138,518 deaths that would have occurred in our army from the four maladies in question had the death rate of the Civil War continued; and against this number we have the actual record of 273 deaths.

This is a record of which modern medicine may well be proud. It tells of the triumph of hygiene on one hand and vaccine therapy on the other. At the time of the Civil War, preventive medicine was in its infancy. To-day, as the records show, it has assumed adult proportions. The typhoid fever record taken by itself stands as a monumental tribute to one of the newest preventive methods,—the vaccine immunization originated by Sir Almroth Wright. This is a product of our own time. The method had not been developed at the time of the Spanish-American War; and it will be recalled that typhoid fever played havoc with our Cuban army. Had typhoid ravaged our army in the present war in the same proportion, the death roll from typhoid would show 68,164 victims instead of the actual 213.

One may not leave the subject, however, without the regretful admission that there is one malady with which the medical science of our day has not learned to cope effectively. The total deaths in our army from pneumonia numbered 41,747, a higher ratio than obtained during the Civil War. The epidemic of influenza was largely responsible for this high death rate. But the fact

that physicians were unable to stem the tide of this invasion shows that there is still abundant work for the innovator in therapeutics.

The pneumonia death-toll was greater than the total roster of men killed in action (36,816 according to official report of March 3rd, 1922). The prevalence of this malady in the home camps accounts for the anomaly that the deaths among enlisted men who did not cross the water numbered 40,237, as against a grand total of 77,692 deaths among our enlisted men in Europe. Disease alone claimed more vicitms on this side of the water than on the other (38,406 officers and men, as against 23,700). Incidentally, we may note that both suicides and executions were twice as numerous among the home troops as among those who went to Europe.

THE ONE GREAT SURGICAL LESSON OF THE WAR

I was talking the other day with a New York surgeon, who had spent two years at the Front, and had personal contact with no fewer than 15,000 surgical cases. I asked him what the war had taught him professionally.

His reply was that the one great lesson that his experience in the war had taught was the value of aseptic surgery in contradiction to antiseptic surgery.

Being interpreted, this means that it is desirable to exclude bacterial germs, if necessary by heroic excision of tissue in the neighborhood of an injury, rather than merely to attempt to destroy the germs by means of antiseptics.

The antiseptic solutions can do something, but it is impossible that they should penetrate to all the

nooks and corners of a ragged wound, and a few microbes remaining out of reach propagate to such advantage that they soon become myriads, and tend to overwhelm the defenses of the body.

When the American surgeon first went to France, he was dumfounded at what he saw in the way of infected wounds. But before the war was over, the lesson of the value of excision—what the French call bebridgement—had been effectively inculcated, and the mortality from wounds greatly lessened.

Stated technically, asepsis had won the day against antisepsis.

The trend of recent surgery had been in the opposite direction, but the teaching of experience, with tens of thousands of these cases under observation, could not be ignored.

Perhaps it should be explained that the difference between aseptic surgery and antiseptic is a difference of method merely; the object of both being to prevent microbic infection from overwhelming the patient.

The triumph of surgery may be told in these salient figures: total killed in action of American officers and men, 36,816; total deaths from wounds received in action, only 13,756. A marvelous record, that.

Let us now turn to consider somewhat more in detail the explanation of the amazing record of medical efficiency in the field of disease prevention.

WHAT MEDICINE DID FOR OUR ARMIES

Soldiers who sent intimate reports from the trenches usually had a good deal to say about the annoyance to which they were subjected by the

visitations of ever-present hosts of little creeping vermin to which they apply the picturesque nickname of "cootie." It was not at first suspected that the pestiferous little beast did any serious harm beyond ruffling the temper of its host; but presently the "cootie" came under suspicion as a possible carrier of disease. The suspicion became a certainty when experiments were carried out on an elaborate scale by American physicians; the work proving that a malady known as trench fever—a debilitating ailment even if not fatal—is a germ disease, and that the germs are carried from one soldier to another exclusively by the little insect in question.

In making this demonstration, experiments were made with the aid of sixty-six volunteers from the American army, whose names, it is gratifying to recall, have been published by the War Department constituting a rather unusual type of roll of honor. The volunteers were subjected to inoculation with the blood of victims of trench fever, both direct and through the medium of the "cootie." Chroniclers of the experiment naturally recall the even more dangerous tests that were made in Cuba by General Gorgas and his associates, in which our soldiers risked their lives in determining that yellow fever is transmitted by a mosquito. The present experiments, if less dangerous, were sufficiently annoying; and the volunteers rendered a service to the entire army. The "cootie" was dealt with in more summary fashion thereafter. Steps were taken to rid the bodies of the soldiers of the little pests, and to disinfect their clothing from time to time. The complete elimination of the "cootie" could

perhaps hardly be hoped for; but at least its depredations were minimized.

It is interesting to recall that the same insect, or a closely related species of body louse, has for some years been recognized as the carrier of the deadly malady known as typhus fever, and that the population of the United States has been protected from epidemics of this malady largely through the vigilance of the health authorities of our Southwestern border who have persistently subjected immigrants from Mexico to the same kind of disinfection which was practised for the benefit of our boys in the trenches in Europe.

There have been hundreds of thousands of deaths from typhus fever in Mexico during the past few years; yet only by rare exception has a case appeared on this side of the Rio Grande; and these isolated cases are prevented from becoming *foci* for the spread of an epidemic solely by rigorous attention to the elimination of the body louse. But for the activities of the health authorities down there in Texas there would have been epidemics of typhus fever spreading across the United States and doubtless claiming tens of thousands of victims.

The widely published report of the activities of the medical service in demonstrating the guilt of the "cootie" as the carrier of trench fever constituted an exception to the reticence of the press regarding the general activities of the physicians and surgeons at the front. Their work was largely taken for granted. There was a general impression that wonderful things were done by the surgeons in the way of repairing injuries; but probably few laymen realize the extraordinary

character of the revolution in the essential conditions of warfare that modern medicine has wrought.

In point of fact, the recent war differed as radically from any antecedent war in its medical aspects as in its purely military aspects. The revolution effected by the airplane and submarine and high explosives and poisonous gases was not greater than the revolution wrought by the hypodermic needle of the physician. Indeed, if the effects are to be measured in human lives, such a comparison altogether understates the case for medicine; for it is unlikely that the total destruction of life by the combined activity of aircraft, submarines, cannon and machine guns constitutes more than a fraction of the lives that were saved through the application of the modern science of preventive medicine.

In proof of this it is only necessary to recall that in most antecedent wars since history began there were from ten to fifty deaths from disease for every death caused by a bullet. The typhoid-fever bacillus has been the deadliest menace to the soldier time out of mind. But in the recent war, thanks to a discovery made less than twenty years before, typhoid fever was practically banished.

Of course typhoid fever is by no means the only plague that has been given virtual quietus by medical science. The allied disease typhus fever threatened the armies for a time on the Southeastern front, and had it been allowed to gain a footing would in all probability have swept the entire battle line. But a vaccine developed along the lines of the anti-typhoid vaccine, combined

with hygiene and measures to guard against transmission, eliminated this menace. Then there is the malady known as Asiatic or bubonic plague,—the "Black Death" of the Middle Ages,—which swept across Europe on occasion, and desolated entire populations, and which found the conditions of army life exactly to its liking. This devastating plague had been banished, not by inoculation to give the individual immunity, but by application of the knowledge that the carrier of the germs in a flea that infests the common rat. The plague is always more or less rampant in some regions of the Orient; but for a good many years the chief ports of Europe and America have been guarded against the invasion of rats that serve as hosts for the germ-carrying flea; so that there was small probability that this deadliest of epidemic maladies would gain a foothold in Europe during the war. Even had such a calamity occurred, however, there is every probability that our medical corps, having a full knowledge of the nature of the malady and its means of transmission, would have stamped it out before it became a general menace.

So long a time has elapsed since smallpox was a dreaded epidemic disease that few persons of the present day realize what that name meant to our ancestors. Until Edward Jenner solved the riddle of prevention of smallpox by vaccination, that malady was an ever-present menace throughout Christendom, and claimed by death ten per cent. of the total population decade by decade. No one worries much about smallpox now, but that is simply because vaccination has proved so effective. If medical science were to relax its vigilance, and

permit a generation of children to go unvaccinated, smallpox would again claim its victims by millions.

Vaccination is not compulsory in Great Britain, but fortunately it is habitual nevertheless; otherwise the Germans would probably have found a way to infect the British army and decimate it far more effectively than they were able to do with shot and shell and nefarious gases.

If we turn from the field of preventive to that of remedial medicine, we find that the records of the war are again instructive and heartening. That medicine should be called upon to heal wounds purposely inflicted by fellow men is an anachronism that has ceased to excite wonder, but there is at least a measure of consolation in the reflection that experiments carried out on a large scale back of the battle lines led to discoveries that may be applied throughout the future for the benefit of unfortunates in the civilian population.

For example, the new Dakin-Carrel method of rendering a wound sterile by irrigation with a solution of a chlorine salt, whereby wounds that formerly would have necessitated amputation of members or have menaced the life of the individual from blood-poisoning are made to heal kindly, is being applied in hospitals and in the practise of surgeons throughout the world.

Similarly, the use of paraffin compounds to give an impervious dressing to burns and scalds, protecting the injured tissues in such a way that they heal with unexampled facility and with the minimizing of permanent scars, is a method that would not have made its way to the average hospital and bedside for many years but for the enlarged

opportunities for testing it made possible by the conditions of warfare.

In the field of psychological medicine there is a similar extension of opportunities for the study of nervous conditions that occur only in rare and isolated cases in civil life, including the development of so-called "shell-shock" due to the horrifying conditions, and in particular perhaps to the perpetual noise, incident to trench warfare with its prodigal waste of ammunition and explosive shells. Perhaps the studies of the great group of victims of "shell-shock" will lead to discoveries in mental medicine that will redound to the benefit of the great company of unfortunates who make up the population of our insane asylums whose hopeless condition has hitherto been a reproach to medical science.

OUR YOUTH 56 PER CENT. DEFECTIVE

Statisticians are making good use of the observations of the draft boards in calling attention to the prevalence of physical defects among the young men of our populaiton.

Needless to say, defects would be much more in evidence if older men were subjected to similar scrutiny; but we are disposed to accept that as the natural result of life's wear and tear. That 468 young men out of every thousand examined should prove defective, however, is rather startling.

The case seems even worse when it is noted that a good many of the men presented two or more defects, so that there was a total of 557 defects for every thousand men examined.

No fewer than 269 different types of defects or

groups of defects were recognized. Needless to say a large number of these were of no great significance, and only a relatively small proportion were such as to cause actual disability from a military standpoint.

Mechanical defects, involving bones and joints, appendages, hands, and feet constituted about 39 per cent. of all noted defects; the second largest group, 12 per cent., comprising defects of the sense organs—chiefly sight and hearing. Tuberculosis and venereal disease competed for third place, each representing about 11 per cent. of all defects; then came diseases of the heart and blood vessels, about 10 per cent., and a similar number of defects classified as "developmental and metabolic." The latter include malnutrition, under size, under weight, curvature of the spine, defective chest measurements, and sundry organic disturbances, including goiter.

GROUPING PHYSICAL DEFECTS BY TERRITORIES

Maps showing the relative prevalence of the various defects among the young men of different regions of the country have peculiar interest. In some cases, the records are very puzzling. The maps showing the distribution of goiter, for example, evidence an extraordinary localization of this defect in two main regions of the United States; namely:

1. The region of the Great Lakes, including the States of Michigan and Wisconsin, and extending (as regards exophthalmic goiter in particular) to Illinois and Missouri in one direction and to Ohio and Pennsylvania in the other;

2. The northwestern region of the United

States, notably the States of Oregon and Washington, extending to Idaho, Montana, and Utah.

By way of contrast, it is noted that the entire tier of Southern States, from Florida to Arizona, have extraordinary freedom from goiter; being listed in a group, which includes also Oklahoma and Arkansas, in which the ratio of goiter is not in excess of one man per thousand. Contrast this with the goiter centers above defined, where the ratio for entire States ranges from 4.51 to 9.48 per thousand.

Other defects showing striking geographical localization include pulmonary diseases, in the Southwest; loss of an upper extremity, in the South; and flat feet in the Northwest and Pacific slope. The nast-named condition is explained by the large body-size of the immigrants into that territory, flat foot being induced in some measure by support of a heavy body.

WHAT CAUSES GOITER?

Goiter, as is well known, is a condition characterized by disturbance of function of the thyroid gland, lying at the base of the neck. In a very large number of cases in which there is disturbance of function of this kind the gland itself is not obviously enlarged. The disturbance of function includes a variety of more or less distressing nervous symptoms, disorders of the digestive system, and over-action of the heart.

In case of exophthalmic goiter, the eyes may protrude in a very characteristic manner. In extreme cases, the toxemia is so marked as to constitute a malady of very pronounced and distressing character. But there are all graduations of

symptoms, and it may safely be assumed that for every case of disturbed thyroid function detected by the medical examining boards there were two or three cases of mild disturbance that escaped detection. But without taking this into account, the recorded observations of the existence of goiter in from four to nine young men per thousand in entire regions of the country is a matter deserving grave consideration.

The importance of the subject is still more manifest when we reflect that goiter is well known to be a condition that is at least five or six times as prevalent among women as among men.

Why should the regions of the Great Lakes and the Northwestern States be especially the seat of goiter?

No one definitely knows. It is known that the thyroid gland has to do with the utilization of iodin in the system; and it has been surmised that goiter regions are regions in which there is a deficiency of iodin in the soil. This suggestion gains a measure of validity from the fact that goiter is known to be prevalent in mountainous regions, such as Switzerland, where the rocks are chiefly of igneous character, suggesting that the iodin originally present was dispelled by volatilization during the time when the rocks were heated. But this explanation does not find obvious application in such regions as Michigan and Wisconsin. Nevertheless, there may be reasons, as yet undiscovered, why there is a dearth of iodin there.

In any event, there is no question that a disturbance of thyroid function is often associated with a lack of iodin, or an improper handling of iodin, in the human system.

Taking a hint from this well-recognized fact, some physicians of Ohio have made the experiment of administering an iodin preparation to groups of girls in the public schools. The results have been very gratifying; the groups of girls so treated showing a very low incidence of goiter—much lower than among corresponding groups of their companions.

It seems desirable that this simple expedient should be adopted in all regions where goiter is unduly prevalent. Obviously, it has application—under the guidance of the physician—everywhere in the case of individual children showing a tendency to disturbance of the thyroid function.

Incidentally, it should be more generally known that cases of goiter, even when fully developed, are usually responsive to medical treatment by modern methods; resort to the knife being much less frequently necessary than was formerly supposed.

CHAPTER X

ASPECTS OF RECENT AIRPLANE DEVELOPMENT

A FAST AND SLOW AIRPLANE

MAKERS and users of the airplane are concerned with the speed problem in two opposite aspects. With regard to each machine there is the question not merely "how fast can it go?" but the equally important question: "How slow can it go?" And each question is answered essentially in terms of size and shape of wings.

Of course the engine power is not to be overlooked; but with the same engine and propeller driven at a given speed one set of wings can give you a very fast machine and another set a very slow machine. And, rather paradoxically, the smaller and flatter the wing the greater the speed. At three miles a minute, the wing is in effect spread out across 264 feet of air per second and a mere ribbon of canvas would suffice. But if you slow down to 30 miles an hour with less than fifty feet of air available per second, you must have wings with dimensions and forms suggestive of a parachute. If the narrow-winged speed machine were slowed down to a thirty-mile gait, it would simply plunge down to the earth like a spent rocket.

So we have airplanes with small, narrow, flat wings, that must attain great relative speed before they can get into the air at all, and call for great skill on the part of a pilot in getting them to earth without crashing, because they must land at high speed; and machines with broad, curved wings that in consequence have great lifting power can rise slowly and land slowly—but also move slowly when at top speed.

What the designer has sought is a machine that will combine the desirable attributes of both types. It is said now that a large measure of success has been attained through the development of what is spoken of as the Dayton Wright "mystery wing." The "mystery" consists in having a relatively narrow flat wing of the type recognized as conducive to speed (because it offers little resistance to the air); but having the rear third or so of the wings "split" or made double, so that the lower part can be swung down on a hinge, somewhat as you lower an awning, and thus made to offer resistence to the air.

In starting you lower the awning and thus get a pull against the wind that lifts the machine into the air at low speed. When in full flight you raise the awning and get the benefit of a flat wing; and when you wish to land, you lower the awning again and thus check the speed so that you can settle down comfortably.

It is said that a plane so constructed has its lifting power so enhanced that it can carry 2,500 pounds of merchandise or explosives instead of 450; and that when in full flight, by flattening the wings, the speed is increased from 125 to 150 miles per hour. The principle involved is ab-

surdly simple, yet unless some unexpected structural difficulty develops, it would appear to solve the problem of the fast-and-slow airplane. We shall have speed and safety combined as never before. The machine equipped with "mystery" wings may have the ponderous strength of the eagle and the celerity of the falcon; the power of a bomber and the speed of a battle-plane.

THE TURBO-BOOSTER AND HIGH FLYING

It is hard to realize that only fifteen years have elapsed since the Wright Brothers created a furor of excitement throughout the world by demonstrating that a heavier-than-air machine could be made to rise from the ground and continue in flight for more than an hour.

Yet in point of fact it was in the year of 1908 that the public demonstration was first made. For weeks together the eyes of the world were focused on Le Mans, France, because Wilbur Wright was doing miracles there from time to time, when weather permitted; his culminating achievement being to accomplish a flight that lasted for "two hours, twenty minutes, and twenty-three seconds." And, incredible as it seemed, he had piloted his flying machine over captive balloons at an altitude of 360 feet! He was even credited with making the wild prediction that it would prove possible to rise to the dizzy height of a thousand feet.

That was fifteen years ago. And to-day an airplane that is a good climber must lift itself into the air at the rate of something like a thousand feet a minute; and it can keep on rising until it is five or six miles from the earth, at an altitude which no bird ever reaches, where the air is so thin that

the aviator must use an oxygen tank to avoid suffocation.

It seems amazing that a gasoline engine, which requires oxygen for combustion, should be able to function in the higher atmosphere. In point of fact, it could not do so, were it not for the aid of a device known as a turbo-booster, which is a turbine actuated by exhaust from the engine and acting as an air pump or compressor delivering compressed air to the carbureter of the engine, thereby keeping up a proper mixture.

In addition to using the turbo-booster, some airplanes are equipped with engines especially designed to operate with maximum efficiency at a high altitude. A Fokker "speedster" has an engine that can not with safety be fully unthrottled at low altitude. Only when the aviator has reached the region of thin air can he "step on the gas" and show what the machine can do.

ELECTRIC CLOTHING

Everyone knows that aviators suffer from the cold, not only at high altitudes, but even in ordinary flights, regardless of season. It seems rather odd, therefore, that there has been so much delay in developing a satisfactory method of keeping the aviator warm.

The solution appears to have been found in electrically heated garments, in particular helmets, gloves, and moccasins.

No new principle is involved; the heating elements are merely coils of resistance wire, placed about seven to the inch, and properly insulated. Energy is supplied at twelve volts, either from a storage battery or from a small fan-driven gen-

erator mounted on the airplane, the fan being rotated by the passing of the plane through the air.

The electricity is supplied at twelve volts, and it has been found that a convenient distribution is twenty watts to the helmet, sixteen watts to each glove, and fourteen to each moccasin. Of course the garments are especially constructed. They may be lined with a non-inflammable artificial wool or with a corklike material to facilitate floating in water.

It is obvious that the use of this method need not be confined to aviators. It might be utilized by automobilists; and, in very cold regions, the applications may be varied. Traffic policemen, night watchmen and sundry other individuals who are exposed to the cold for protracted periods, might be warmed from ordinary electric-light currents, and truckmen could be warmed by storage batteries.

Once the idea is suggested, its applications are obvious. And the result would be, not only an enhanced degree of comfort for a great many people, but a marked reduction in the rate of death from pneumonia.

SEEING FROM AN AIRPLANE

It is obvious that the problem of navigating airships must practically be solved before long-distance voyages, particularly over the water, can be made reasonably free from hazard. Naturally the problem has received much attention in recent years, and a measure of success has attended the efforts of the investigators.

When the airplane is voyaging above the level land or in sight of a water surface that chances

to be free of mist there is no great difficulty. The ordinary sextant may then be employed just as by the navigators of ships. Allowance must be made for the fact that observation is made from a height. The observer must know the elevation at which the airplane is progressing. The square root of the height in feet is the equivalent of the "dip" in minutes of arc.

The reason why this "dip" must be taken into account will be obvious if we reflect that the curved surface of the earth makes the horizon drop lower and lower with increasing distance.

The horizon observed from the airplane may be one hundred miles away; and in that distance the slope of the earth falls away from the tangent by 6,600 feet.

The line of vision to such a horizon obviously will not be parallel with the horizon line from the deck of a ship.

TEMPERAMENTAL HORIZON LINES

It is rarely possible, particularly over the water, to view the actual horizon at a great distance, owing to the haze. The object at which the navigator must usually sight is the top of a ridge of haze (in effect a cloud-bank) which often is approximately level.

In actual observation, such an apparent horizon has been observed at a distance of a hundred miles, lying at a height of 14,800 feet. Allowing for the 6,600-foot curvature of the earth, this places the cloud-bank 8,200 feet above the level of the sea at the point of observation. If the airplane making the observation chance to be at this height, there is no "dip"; and below this height, the dip

is negative—that is to say, the line of sight tilts upward from the horizontal.

But how is the observer to know the height of the ridge of haze or cloud that serves for horizon? Sometimes this can be tested directly as the airplane rises through the haze. When this can not be done, the height of the cloud-bank must be estimated, and this introduces an element of uncertainty. This is unsatisfactory, so other methods of determining the horizontal have been devised. One of these is based on the problem of finding a true vertical by means of a pendulum oscillating slowly in a viscous liquid.

There is great difficulty in using this method, however, owing to the non-uniform motion of the plane. If the observation is to be accurate within fifteen minutes of arc, the speed of the plane must not shift at a rate exceeding one mile per hour during the ten seconds required for the observation; nor must the plane depart from a straight line in its forward flight by more than an infinitesimal amount. Its path must not curve more than the arc of a circle of ten-mile radius. It is said that a skillful pilot can so guide his plane as to meet these conditions.

A MAGIC WAND OF THE AIR

A better solution of the problem of determining the horizontal has been found, however, by using a sextant which establishes its own horizontal by means of a level-bubble, which is reflected into the field of view of the telescope in such a way that any object that appears to be superimposed on the center of the bubble will actually be on the true horizon.

A set of observations with this instrument can be made in about four and a half minutes. Three additional minutes are required for computation and two minutes more to plot the so-called Sumner line, substantially establishing the location.

It is said that with this apparatus the average of a series of observations may show an error of only ten miles, which is accurate enough for all practical purposes. Greater accuracy than this can hardly be expected, considering that the plane is changing its location by a mile or more during each minute of the observations.

But even with such limits of variations the bubble-sextant in the hands of the aeronaut up there above the clouds seems a veritable magic wand.

SNUBBING THE ATLANTIC

Every one knows that about the only hazard in flying across the Atlantic in a well-constructed airplane arises from the probability that your motor will give out when you are half-seas-over.

Granted a motor guaranteed to run for twenty consecutive hours, you could snap your fingers at the old inter-continental pond.

And that is the kind of a motor that no less an authority than Edson F. Gallaudet assures us is now available. Moreover, he further guarantees that a hundred-foot all-metal monoplane, equipped with his new engine, can make 150 miles an hour, for said twenty hours with twelve passengers aboard.

Mr. Gallaudet estimates that the transatlantic flight or a corresponding flight from California

to Hawaii can be made for less than $700 per passenger.

The new engine which thus promises to enable us to ignore the ocean represents a novel application of old ideas rather than an engineering discovery. Its essentials are three 400 horse-power Liberty engines geared in tandem to one eighteen-foot propeller, but so adjusted by ingenious use of the principle of the automobile clutch that whereas the engines develop 1,800 revolutions per minute, the propeller is slowed down to 800 revolutions, being much more efficient than if operating at higher speed.

Add that the engines can be operated singly, in duplicate, or in triplicate at will, and that under ordinary conditions of flight, one engine would always be kept in reserve (giving obvious opportunity for making repairs if necessary during transit), and it will be clear that, theoretically at any rate, the greatest danger that menaces the long-distance flyer has been minimized or almost eliminated.

ROUND THE WORLD IN TWENTY-FOUR HOURS

It was seriously suggested by a French engineer before the Aeronautical Congress in Paris not long ago that it might soon be possible to fly from Paris to Paris via the Atlantic Ocean, the American Continent, the Pacific Ocean, and Asia in twenty-four hours. The suggestion seems fantastic, until we reflect that the earth turns clear round in the time suggested. Then it is obvious that everyone of us does, in effect, make a journey round the world every day. And the thought

emerges that if one were able to go up into the air and hold oneself stationary there, the surface of the earth would whirl by so that one would in effect journey westward at the rate of something like a thousand miles an hour.

The difficulty is that in going into the air we carry the earth's momentum with us, and that even the swiftest airplane, flying westward, can neutralize only a small fraction of this momentum. But now it is suggested that if an airplane were to rise—with the aid of the turbo-booster for condensing air—to an altitude of eight or ten miles, the atmospheric resistance would be so slight that the flying machine might presently attain a speed comparable to that of the earth's rotation. Then, of course, the round-the-world journey becomes feasible.

The thing might be done just as well near the earth were it not for atmospheric resistance. Nothing but that prevents an airplane flying in a straight course from attaining constantly accelerated speed, just as an object does under influence of gravitation when falling from a great height. The airplane which has attained an enormous speed at a great elevation must descend rather slowly, and thus have its speed checked gradually, or its wings would be stripped off by air pressure as dead leaves are stripped from the branch of a tree by a hurricane.

The writer long ago suggested the theoretical feasibility of the twenty-four-hour airplane journey round the world. It is interesting to observe that professional aviators are now giving the problem attention.

CONQUERING TIME AND SPACE

In the latter part of the year 1922 two notable airplane triumphs were recorded. An airplane out in California made a continuous flight of more than thirty-five hours; and an airplane on Long Island attained a speed of 248.5 miles an hour—something over four miles a minute.

These are attainments that a few years ago would have seemed unbelievable. It is but thirteen years since Orville Wright won governmental recognition by remaining aloft in a test flight for an hour; while almost simultaneously his brother Wilbur established a speed record of 38 miles an hour. And now—35-hour flights, and 248 miles an hour!

Lieutenant R. L. Maughan, the pilot of the airplane that made the record speed flight, probably went through the air at a higher rate of speed than was ever attained by any living thing on the earth before.

Compare his speed with other record-breaking speed tests. A human sprinter covers 100 yards in ten seconds. In the same time, a fast thoroughbred runs 176 yards; a fast trotter covers 146 yards; a carrier pigeon flies 300 yards.

But the airplane in the same time travels 1,215 yards. It goes more than four times as far as the pigeon.

In an hour's race, if both kept at top speed, the airplane could fly in circles and still outdistance the pigeon. Or it could fly straight to the goal sixty miles away; turn about and fly back to the starting point; and turn again and retrace its course, passing the pigeon before it reached the goal.

The swiftest bird is an indifferent flier pitted against the modern man-bird. Neither in altitude nor in distance nor in speed tests could the bird compete successfully. There is only one kind of flying in which the bird would win—and that is slow flying. The airplane can not slacken its speed below a certain minimum, or it will drop to the ground. Neither can the bird, of course; but its minimum is far below that of the airplane.

But even this supremacy will not long be left the bird. Soaring tests are teaching man how to keep in the air while going slowly; and the helicopter, when perfected, will enable them to stand still in the air—as one "treads water" when swimming.

In this field, as in every other, man's ingenuity ultimately enables him to outdo the best efforts of all animate competitors.

All *animate* competitors. But not the exhibitions of inanimate nature's powers. If we tend to become vainglorious about the 248-miles-an-hour airplane flight, let us "pause and reflect" on the thousand-mile-per-hour speed of the earth's revolving surface; or the 12-mile-per-second speed of the solar system through space—not to mention the 186,000 miles per second of light and radiant heat and radio waves.

All speeds are relative, and man's conquest of time and space is significant only to himself.

A NEW TYPE OF AIRSHIP

Broadly speaking, only one type of airplane has hitherto been in actual operation. This is the apparatus of which the Wright biplane was the type specimen, which owes its buoyancy to the

principle of the flying kite, and its stability to the fact that its wings can be warped, so that they offer greater or less resistance to the air, and thus serve as balancers. Such modifications as leaving off one pair of wings; putting a propeller in front; adjusting bicycle wheels or a boat-bottom under the machine; and utilizing little wings called ailerons in place of warping the big wings—these are only details that do not constitute essential departures from the original principles utilization of which enabled Wilbur and Orville Wright to perform their miracle.

But of late very strenuous efforts have been made by inventors in all parts of the world to produce a machine to operate on a different principle. The proposed new type is called a helicopter, because operation will be dependent upon a whirling about of a helix, or perhaps two or more helices, of such size and strength as to be able to lift the apparatus directly into the air, instead of dragging it along to slide up on an inclined plane of compressed air as does the ordinary airplane.

The helix, after all, is only an enlarged propeller, tugging at the air when it rotates, just as the ordinary propeller does; but its enlarged dimensions, and its adjustment above the machine in a horizontal plane, seem to constitute it something of another order. And the fact that it must lift the plane, directly overcoming the pull of gravitation, introduces, as has been said, a new principle. No Wright airplane, of original type or any of its modifications, is designed even to attempt that feat.

If the helicopter works successfully, it can rise directly into the air, and can hover there without going forward or backward, affording certain obvious advantages in bomb dropping or in making observations; and can settle directly to a landing place not much exceeding its own size; whereas, as everyone knows, the ordinary airplane requires a large field for safe landing as well as for taking off.

As to progressive motion, the helicopter could theoretically accomplish this by shifting its helices, so that they pull the apparatus forward at one angle or another. In practise, a helicopter that Mr. Henry A. Berliner, of Washington, has exhibited is made to go forward, after raising itself a few feet into the air, by adjustment of the horizontal rudder. It should be added, however, that the Berliner helicopter has not hitherto been caused to operate at a greater height than twelve feet.

Meantime it does not appear that other helicopters, of which there have been many reports, have gained even this elevation. In fact, so far as can be judged, the present status of most of the experimental helicopters is that of the apparatus of which Wallace Irwin made his famous Japanese schoolboy say that it appeared to be a practically perfect flying machine, its single defect being that it would not fly.

Some day the helicopters will fly; but they will not soon be regarded as thoroughly safe machines in which to find oneself up in cloudland; for one of the inherent characteristics of the helicopter as at present conceived is that, wherever it happens to be, should the engine go wrong, it will drop to earth with the directness and force of so much lead.

GLIDING VERSUS FLYING

Necessity, the proverbial mother of invention, has led the Germans, denied the right to experiment overmuch with flying machines, to investigate the possibilities of gliding flight, with a motorless airplane. Everyone has heard of the somewhat astonishing results attained; and it is not surprising that new interest should have been aroused in a department of aviation that has been somewhat neglected since the day when Wilbur and Orville Wright attached a motor-driven propeller to their glider, and made it into a veritable flying machine.

In 1922 international gliding contests were held in Europe; and as was to be expected new records were established. It was not altogether surprizing that some of the competing machines were able to remain aloft, buoyed by the wind, like soaring birds, longer than did the original Wright biplane during those record-breaking tests of 1908, which all the world regarded with bated breath. But who would have predicted flights of over three hours? Yet the 1922 records tell of a flight by Lewes, in England, using a motorless tandem monoplane, lasting three hours and twenty-one minutes (October 21, 1922); and of the German champion, Gersfeld's best effort, in which he remained aloft three hours and seven minutes.

It should not be forgotten that all airplane flight is in reality gliding. The motor-driven

propeller insures forward motion only, and would be quite incapable of lifting the heavy apparatus, which rises merely because it is supported on a cushion of air. If a glider can make its start from a hillside, so that gravitation may develop momentum, there is no reason why it may not slide upward on the air cushion, just as the motor-driven airplane does; and with a strong breeze to aid, there is no obvious limit to the time that it may remain aloft, like a kite or a soaring bird.

In still air, on the other hand, the time of gliding flight must be strictly limited. You can not fly a kite in still air unless the holder of the string moves forward rapidly; and it is more than doubtful whether a bird can soar indefinitely unless aided either by a breeze or by occasional flapping of the wings. There is no string to pull the glider forward, and it can not flap its wings.

It will be recalled that those pioneer aviators, the Wright brothers, taught themselves how to fly by using a glider; that Wilbur Wright was interested in the gliding apparatus to the time of his death, and that his surviving brother, Orville, continued to make experiments with a gliding apparatus up to the time when his commercial affiliations made it seem inexpedient to take further air hazards.

The recent success with gliders tends to justify the confidence that the Wright brothers manifested in the motorless airplane after they had demonstrated the value of the motored one. The glider is no mere "stunt" apparatus, as is sometimes assumed. It can teach important lessons in the art of flying.

THE AIRPLANE AS A FARM IMPLEMENT

The time is probably not far distant when the airplane will be made so safe and so cheap a vehicle that it will largely supplement the flivver in the equipment of a good many farmers, particularly in regions where, owing to climatic conditions, the roads are nearly impassable for considerable periods each year. The landing-place problem will be met so soon as the general need arises, as also the cost-price; and another highly important step will have been taken toward bringing town and country together and making farm life more attractive.

When the farmer can hop aboard his air-flivver and visit any city within a hundred miles or so as readily as he now visits the neighboring village (and more readily in time of bad roads), the idea of isolation that now proves so repellent will no longer obtain. The "back to the land" movement may then gain headway.

Meantime it appears that the airplane may have a quite different field of utility in connection with the farmer's activities. Perhaps the first illustration of such possibilities was given when a farmer near Dayton, Ohio, sought the cooperation of the McCook Experimental Post at Dayton, where engineering work with government airplanes is carried on, and received the cooperation of Lieutenant John MacCready in having an airplane raid projected against the destructive insects that were preying on a grove of trees. The farmer could spray the lower branches of the trees, but not their tops, where the insects were most active. Lieutenant MacCready came to the rescue with an airplane carrying one hundred

pounds of insect powder which could be sifted out at will, as a housewife sifts flour.

Flying very low over the tops of the trees the aviator sprinkled the insecticide effectively, at once aiding the individual farmer, and demonstrating a new use for the airplane.

This is perhaps the first practical use of the airplane for purposes other than those of warfare or transportation. Conceivably the method may be modified for application against numerous pests, from grasshoppers to wheat-rust and allied fungi, and in any event it is certain that practical uses will be found for the airplane which even a vivid imagination could not forecast. It is fitting that this first application of the airplane to the needs of a great industry should have been made at the home of the Wright brothers, to whose genius the world owes the airplane itself.

PRACTICAL FLYING

It is perfectly natural, in looking back across the vista of the past, to divide history into eras and epochs. The philosophical historian, however, reminds us that the changes which we think of as being epochal, probably were slow developments that scarcely impressed themselves at all on the generality of people of contemporary ages.

A case in point is the fabled cataclysm through which the Roman Republic became the Roman Empire. In point of fact, the transition was gradual in the extreme, and the Romans of the later period continued to talk officially of the Republic long after the body politic had ceased to deserve the name, according to the modern interpretation. A Roman of the second century

A. D. would have resented the implication that his famed republic was a thing of the past and that an autocratic empire had taken its place, as bitterly as the average American of to-day would resent the implication that the present trend of our own governmental system is toward autocracy.

With the justness or the validity of such a suggestion, we have no present concern. I cite the Roman instance merely to emphasize the fact that events leading to great social and economic and political developments may in themselves seem so trivial as to be almost overlooked in the contemporary hurly-burly. The event that I had in mind,—an event which, in my opinion, adumbrates economic and political changes of which few people have the remotest inkling,—was the first utilization of the airship in America as a commercial vehicle in 1918. It is true that the newspapers took note of the event, and that for a few days it was more or less talked about. But after that the United States Aerial Mail Service was simply taken for granted by persons who availed themselves of its services, and for the most part quite forgotten by the rest of the world. There was no burst of applause on its first anniversary, and various extensions of the service were carried out so quietly as scarcely to claim even passing attention.

Yet the tangible accomplishments of the first year of air services were notable in the extreme. It is recorded that out of a total of 138,310 miles that might possibly have been flown in carrying out the service, no less than 128,255, or 92.73 per cent., were actually flown. Only 4.41 per cent. of

daily trips were not attempted or if attempted failed,—35 out of a total of 1,233. The aggregate amount of mail carried was 193,021 pounds, and the government netted a profit of $19,103,—a sum insignificant in itself, but notable in its complications.

Meantime there was but one serious accident, and no death resulted. Only ten years had elapsed since the Wright brothers, in making their spectacular demonstration, had been obliged to wait day after day for favorable weather, and never thought of attempting a flight if there was more than a moderate breeze. Only five years had passed since Blériot's feat of flying thirty miles across the English Channel was regarded as phenomenal. But for that matter only fifteen years had passed since the very first flight of the Wright brothers had confounded the scientific skeptics and proved that the age of miracles is our own era.

The second year of practical air transportation was scarcely under way before both airplane and dirigible balloon had spanned the ocean, preparing the way for international aerial commerce. It would be a weirdly sagacious prophet who could forecast with accuracy the commercial development and international significance that the new vehicle will attain before the United States Aerial Mail Service celebrates its first decennial.

END OF VOLUME VIII